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# ENTOMON

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# Relationship between egg maturation and oviposition and evidence of factors regulating these events in male ejaculatory duct duplex of *Helicoverpa armigera*

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ABSTRACT: In synovigenic female *Helicoverpa armigera* (Hubner) mating enhanced both reproductive potential (egg maturation) and reproductive output (oviposition). This increase in egg maturation and oviposition in mated female could be brought about in virgin females by treating them with factors isolated from male accessory glands and ejaculatory duct duplex. Egg maturation process could also be stimulated by methoprene treatment but not by provision of additional nutrients. The enhanced rate of oviposition that was induced by mating or male derived factors was not a consequence of enhanced egg maturation. 

KEYWORDS: *Helicoverpa armigera*, egg maturation, oviposition, duplex factor, methoprene

## INTRODUCTION

In insects, the reproductive potential of the female is determined by the total number of mature eggs present in the ovary while reproductive output is dependent on the total number of mature eggs deposited. Pro-ovigenic insects like *Bombyx mori* that do not feed as adults contain a full complement of mature eggs at the time of eclosion and therefore are reproductively potent as adults (Geethabali and Manjulakumari, 1987). But synovigenic insects emerge as adults with immature eggs and a number of factors are shown to enhance their reproductive potency i.e., total number of eggs matured. Of the various factors, adult diet, juvenile hormone and mating play an important role in egg maturation (Park and Ramaswamy, 1998; Park *et al.*, 1998). Besides mating, transplantation of male derived substances extracted from one or more reproductive tissues into the female body cavity is shown to enhance egg maturation (as reviewed by Gillott (2002, 2003); Leopold (1976). In both pro-ovigenic (Manjulakumari and

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Geethabali, 1996) and synovigenic insects (Yi and Gillott, 2000; Schmidt *et al.*, 1993) mating or transplanted male derived substances are also shown to enhance reproductive output i.e., oviposition. Whether oviposition and egg maturation go hand in hand or oviposition is the result of enhanced egg maturation in synovigenic insects is not clearly understood.

In cotton bollworm, *Helicoverpa armigera* (Hubner), a synovigenic insect, the male reproductive system is similar to that in other noctuids. In this moth, the testes (T) and accessory glands (Acg) open into the ejaculatory duct duplex (Ed); thus Ed can act as a reservoir for secretions of both accessory glands (Callahan, 1958) and testes (Lachance *et al.*, 1977; Proshold, 1991). Hence it is possible that the factors derived from either Acg or Ed can have similar functions.

Studies hitherto in *Helicoverpa* species have shown that factors derived from combined Acg-Ed temporarily inhibit calling and receptivity in treated females (Kingan *et al.*, 1993, 1995; Nagalakshmi *et al.*, 2004). But a lacuna exists in understanding the role of Ed derived factors in altering the egg maturation and oviposition behavior of the female although Jin and Gong (2001) have recorded that Acg derived factors stimulate both the phenomena in this insect. Therefore this study was conducted to examine the role of Ed derived factors in regulating egg maturation and oviposition in *H. armigera*. The study was further extended to examine if enhanced rate of oviposition is a consequence of enhanced egg maturation.

## MATERIALS AND METHODS

### Animals and dissections

Continuous rearing of *H. armigera* was done in laboratory. The colony was maintained under a 16L: 08D photoperiod and temperatures of 25 and 21 °C, during photo- and scotophase, respectively. The larvae were reared on artificial diet (Shorey and Hale, 1965) individually in 30 ml vials. The male and female pupae were maintained separately in mosquito net cloth cages (45 × 30 × 30 cm) till emergence to avoid mating. Emerged female moths were transferred individually to oviposition chambers (7 × 5 × 2 cm, Bellaplast, Germany) after mating or otherwise. As adults are known to feed on nectar in the fields they were provided with cotton dipped in 10% honey.

The male reproductive systems from day-2 virgin males was removed carefully and rinsed in ice-cold saline (Bindokaas and Adams, 1988). The ejaculatory duct, accessory glands, and testes with seminal vesicles were cut and pooled separately from 50 insects and stored at −80 °C until used. The proteinaceous factors from these tissues were extracted in acidic conditions using Bennett's buffer (Bennett, 1986) and desalted using C-18 Sep-Pak cartridge (Waters, USA) as described by Kingan *et al.* (1993). Thoracic muscle from day-2 male moths was used as a control tissue. All the dissections were carried out after two hours of onset of scotophase.

**Bioassays**

The biological activity of the proteinaceous factors in different reproductive tissues was determined by bioassays. The bioassay experiment consisted of 5 groups of 30 each day-2 virgin females. They were respectively injected with saline, Ed extract, Acg extract, testes with seminal vesicle extract and thoracic muscle extracts. 3 $\mu$l of saline or tissue extract (one moth's respective tissue equivalent for reproductive tissues and 1 pair Acg-weight equivalent for thoracic muscle was injected through the inter-segmental membrane after anaesthetizing the females with $CO_2$. All the treatments were carried out during the scotophase in dim red light; between 1–2 AM as peak calling activity was observed during this period. The treated moths were transferred to a new oviposition chamber (OC) daily to facilitate the counting of the number of eggs laid. For demonstration of egg maturation, 5 females in each group were dissected every day at the end of scotophase for six days after injection or mating. The number of chorionated eggs retained in the ovaries along with eggs oviposited gave the total number of eggs matured.

**Methoprene treatment**

1 $\mu$g of methoprene in 5 $\mu$l acetone was applied to each of 30 virgin females during the first scotophase as described by Bali *et al.* (1996). Acetone applied females served as control. Oviposition was monitored in these moths and chorionated eggs were counted at given intervals. To check if presence of mature eggs stimulates oviposition we treated virgin day-2 females with methoprene prior to the injection of Ed or Acg extracts and the results were recorded for a day only.

Normal pattern of oviposition and egg maturation was observed in day-2 mated and age matched virgin females and these moths served as untreated controls. The results of experiments in triplicates were expressed as mean ±SD. Data obtained were subjected to ANOVA and Student-Newman-Keuls test.

The total fecundity during the observation period was calculated by adding the total number of eggs laid to the number of chorionated eggs retained in ovary. Oviposition index was calculated as Number of eggs laid ×100/Number of eggs matured.

RESULTS

**Egg maturation and oviposition in untreated females**

The females on the day of emergence did not have chorionated oocytes in their ovaries and did not exhibit calling or mating behavior. On day-2, the mated moths matured 234 ± 30 eggs, 19.5 times more than that in virgin females. The counts of mature eggs in mated females when compared to virgin females was significantly higher ($p < 0.001$) on following days also (Fig. 1), clearly indicating that mating is a powerful stimulus for egg maturation.

The females did not lay eggs on the day of emergence. On day-2 both the virgin and mated females laid a few eggs, 4 ± 2 and 7 ± 3, respectively. On subsequent days,

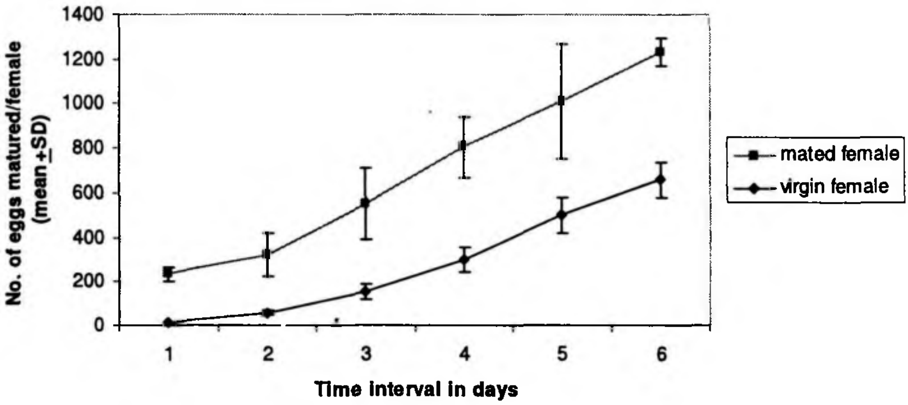


FIGURE 1. No. of eggs matured by untreated virgin and mated *H. armigera* for six days.

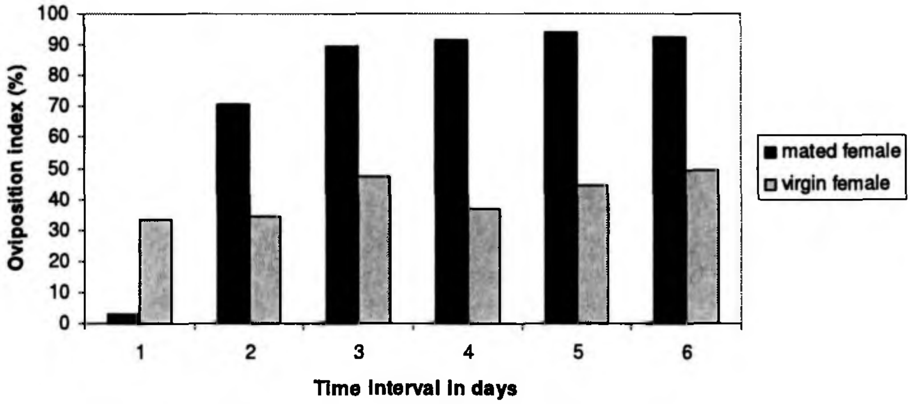


FIGURE 2. Oviposition index of untreated virgin and mated *H. armigera* for six days.

the mated females always laid >70% of the total eggs available to them i.e., mature eggs, while the virgin females laid <49% on any day (Fig. 2). The total fecundity of the mated moths was 1232 ± 62 which was 1.7 times that of virgin female and was statistically significant ($P < 0.001$).

## Egg maturation and oviposition in treated females

The number of eggs matured in both saline and thoracic muscle injected controls was not significantly different during the first three days of observation (Fig. 3) but more eggs were matured during subsequent days in the thoracic muscle-injected moths than in saline-injected moths. When compared to saline injected controls (15 ± 8) or testes with seminal vesicles (6±4) treated females, Acg (135±47) and Ed (168±33) treated

TABLE 1. Number of eggs matured by *H. armigera* females following treatment with methoprene

| Treatment | Days after treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Females treated with methoprene | $289 \pm 61^{c}$ | $550 \pm 43^{d}$ | $625 \pm 88^{e}$ | $756 \pm 62^{f}$ | $798 \pm 56^{f}$ | $986 \pm 70^{g}$ |
| Females treated with acetone (Controls) | $16 \pm 5^{a}$ | $120 \pm 23^{b}$ | $339 \pm 51^{c}$ | $413 \pm 33^{d}$ | $460 \pm 42^{d}$ | $556 \pm 54^{d}$ |

$N = 6$ for all groups
Means followed by different letters in both rows and columns are significantly different at $p < 0.05$.

females matured more number of eggs on the day of treatment and the trend continued even on subsequent days similar to mated female.

Oviposition by females that were injected with thoracic muscle extract and testes with seminal vesicle extract was similar to that in the saline injected females for the first three days after injection but slightly increased on day 4 and day 5 in thoracic muscle injected and on day 5 in testes with seminal vesicle injected females. On the other hand, following treatment, the females injected with Acg extract or Ed extract laid only few eggs during the first 24 h period but oviposition increased significantly after the 2nd day and the trend continued during the subsequent days. There was no significant difference between these two groups in the number of eggs laid on all the days ($p > 0.05$) (Fig. 4). The increase in oviposition by either thoracic muscle extract injected females on day 4 and day 5 or testes with seminal vesicle extract injected on day 5 was not comparable to mated moths though the increase in thoracic muscle extract injected females was significant compared to saline injected females

### Egg maturation and oviposition after methoprene treatment

The total number of mature eggs in methoprene treated moths was significantly higher when compared to controls and was comparable to that of mated moths (Table 1). However, the number of eggs laid by these moths was very few during the test period (Table 2). Similarly the females injected with Acg and Ed extracts post methoprene treatment though matured $251 \pm 32$ and $332 \pm 56$ eggs respectively laid only $10 \pm 4$ and $13 \pm 8$ eggs on the day of treatment.

## DISCUSSION

In the synovigenic *H. armigera*, both reproductive potential (egg maturation) and output (oviposition) are enhanced by mating. Our results suggest that although mating

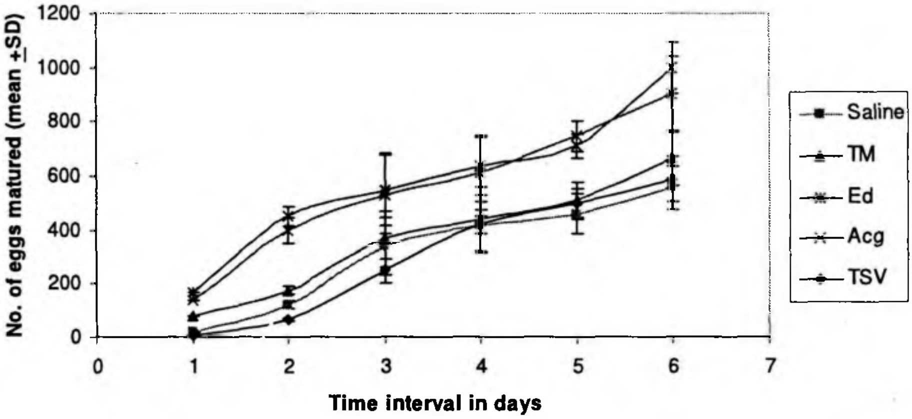


FIGURE 3. No. of eggs matured by *H. armigera* females for six days following treatment with crude tissue extracts (TM, Thoracic muscle; Ed, Ejaculatory duct duplex; Acg, Accessory gland; TSV, Testes with seminal vesicle).

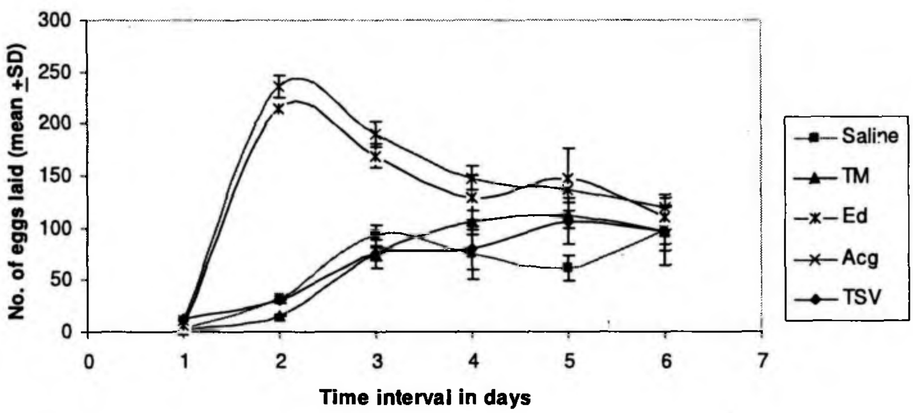


FIGURE 4. No. of eggs laid by *H. armigera* for six days following treatment with crude tissue extracts (TM, Thoracic muscle; Ed, Ejaculatory duct duplex; Acg, Accessory gland; TSV, Testes with seminal vesicle).

increases the rate of oviposition, this process was delayed by a day. Treating the virgin females with methoprene was an option to test whether this delay was due to the absence of mature eggs. Topical application of the Juvenile hormone (JH) analog methoprene matured the eggs faster in virgin *H. armigera* but did not stimulate oviposition. These results seem to suggest that delayed stimulation of oviposition was not related to the absence of mature eggs in the ovaries. Bali *et al.* (1996) had also shown that presence of mature eggs did not stimulate egg laying in *H. zea* moths. In many Lepidoptera, JH is crucial for egg maturation and/or production (Ramaswamy *et al.*, 2000; Shu *et al.*, 1998). In *H. virescens* (Ramaswamy *et al.*, 2000) mating

TABLE 2. Number of eggs laid by *H. armigera* females following treatment with methoprene

| Treatment | Days after treatment | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Females treated with methoprene | $6 \pm 2^{a}$ | $49 \pm 16^{b}$ | $36 \pm 22^{b}$ | $51 \pm 13^{b}$ | $27 \pm 9^{b}$ | $29 \pm 8^{b}$ |
| Females treated with acetone (Controls) | $13 \pm 2^{a}$ | $43 \pm 10^{b}$ | $71 \pm 12^{c}$ | $92 \pm 23^{c}$ | $87 \pm 13^{c}$ | $61 \pm 15^{b}$ |

$N = 6$ for all groups
Means followed by different letters in both rows and columns are significantly different at $p < 0.05$.

not only resulted in transfer of male derived JH to the female, but also stimulated corpora allata of the mated female to biosynthesize JH and inhibit the JH-degradation pathway. This resulted in increase in JH titers in mated female's hemolymph, which in turn stimulated egg maturation and production. Our hypothesis is that male factors transferred during mating, induce JH production in mated female which in turn stimulates egg maturation; but stimulation of oviposition is not solely dependant on JH biosynthesis.

The secretary epithelia that line the male reproductive tract in insects is not only associated with accessory glands, but also testes, seminal vesicle, ejaculatory duct and other associated structures as reviewed by Gillott (1988). But studies in many species have credited Acgs as the source of male derived factors (Chen, 1984; Leopold, 1976). Our study shows that the source is not only Acg but also Ed and not testes with seminal vesicle. Since the extraction method (using highly acidic Bennett's buffer) used in this experiment eliminated lipids, carbohydrates and high molecular weight proteins, the factor/s responsible are possibly low molecular weight proteins/peptides. In *Helicoverpa* species, Ed not only contributes to spermatophore formation by secreting some of the seminal fluid components but also acts as a storage organ (Callahan, 1958). The secretions of testes, seminal vesicle and Acg are stored in Ed. The role of stored testes and seminal vesicles products in stimulating the egg maturation or oviposition can be ruled out as the testes with seminal vesicles products by themselves did not influence this process. But it is not clear whether the post-mating changes are brought about by Ed secreted products or Acg products that have descended into the Ed for storage. Further purification of the crude extracts is necessary for establishing their role.

The present results also suggest that the changes in female physiology brought about by Acg or Ed extracts was not as a result of provision of additional nutrients since females injected with thoracic muscle extract laid and matured eggs comparable to that

of virgin as well as saline injected females. Satyanarayana *et al.* (1991) had observed that addition of nutrients increased oviposition in *H. viresecens*. Our hypothesis that increase in egg laying was not because of enhanced egg maturation was further strengthened, when moths treated with both methoprene and male derived factors (Acg/Ed) did not lay eggs on the day of treatment although chorionated eggs were present in the ovary. Apparently, the stimulus for egg maturation and oviposition is blood-borne, since injection of Acg/Ed extracts into the body cavity induced these changes. Similarly Manjulakumari (1991) was able to induce oviposition in virgin *B. mori* by injecting Acg factors into the body cavity. Earlier work by Davey (1967) on *Rhodnius* had shown that implantation of mere spermatheca will increase oviposition.

In ovigenic moth *B. mori*, studies in our laboratory have shown that a 45Kda oviposition stimulating protein triggered electrical activity in the nerves emerging from the terminal abdominal ganglion innervating the musculature of the ovipositing apparatus (Manjulakumari, 1991). We were not able to reproduce similar results in *H. armigera*. This may be because we used crude extracts or the egg laying process is stimulated by a different mechanism in synovigenic insects.

Our results do not clarify whether the blood-borne stimulant is the male derived factor *per se* or is another material whose release has been promoted by the male factor/s. In related studies, circumstantial evidence strongly indicates that the effect of male factors is induced indirectly, via the brain, corpora allata, and it is the neurosecretion that directly promotes oviposition (Davey, 1967; Leopold *et al.*, 1971). The Acg factors may move across the spermathecal wall into the haemolymph and hence to the brain in *M. sanguinipes* (Friedel and Gillott, 1976). Though it remains to be shown that Acg/Ed products can act directly on the corpora allata in *H. armigera*, it has been reported that synthetic *D. melanogaster* Sex peptide stimulates *in vitro* JH synthesis by the corpora allata of virgin female *H. armigera* (Fan *et al.*, 1999, 2000). Whether the Acg/Ed derived factors regulate the JH biosynthesis by corpora allata, or trigger oviposition by any other mechanism remains to be elucidated. Ultimately it is only the identification of receptor site(s) which will indicate whether the brain is, in fact, the primary (or secondary) target for male derived secretions.

## ACKNOWLEDGEMENTS

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# Diversity and abundance of insects in a cropland of central Himalayan Bhabar region of Kumaun, Uttarakhand

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ABSTRACT: Species richness, population density and biomass, species and trophic diversity, secondary production and herbivory of aboveground insects were studied in a cultivated land of central Himalayan Bhabar region of Kumaun, Uttarakhand from 2005–2007. A total of 54 plant species were recorded in the cultivated land and mean aboveground net primary production was 2351 kJ $m^{-2}$ $yr^{-1}$. A total of 88 species belonging to 9 insect orders and 33 families were collected. Herbivores, predators, parasites, and omnivores constituted the insect community of which herbivores were most preponderant. Maximum population density and biomass were 7.8 $m^{-2}$ and 1456.4 mg $m^{-2}$, respectively. Shanon-Wiener species diversity index H ranged from 1.00 to 1.44, and of trophic levels ranged from 1.18 to 1.43. Mean secondary net production due to herbivores was 147.6 kJ $m^{-2}$ $yr^{-1}$. Herbivores consumed an average of 7% of plant biomass. 

KEYWORDS: species richness, population density, biomass, consumption, species diversity, trophic levels, secondary formation

## INTRODUCTION

The structure of agricultural landscape due to intensive cultivation exerts a major impact on the standing crop and richness of the fauna of ecosystems (Ryszkowski, 1985). Composition, abundance and diversity of species in different crops have been the object of intensive studies (Ryszkowski *et al.*, 1993; Grutzmacher and Link, 2000; Kandibane *et al.*, 2004).

The present investigation is aimed at understanding certain structural and functional aspects of a cropland community in central Himalayan bhabar region of Kumaun. The main objectives of the investigation were to determine species richness, population density and biomass, species and trophic level diversity, secondary net production and insect herbivory in a cropland ecosystem from March 2005 to February 2007.

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## MATERIALS AND METHODS

The site is a 1 ha area of cropland at Kathgodam (29° 16′ N latitude and 79° 31′E longitude; 553 m altitude) with an annual rainfall of 1400.3 mm. The maximum temperature ranged from 21.1 °C (January) to 36.9 °C (June) and the minimum temperature ranged from 6.1 °C (January) to 25.5 °C (July). The maximum relative humidity ranged from 65% (May) to 91.9% (January) and minimum relative humidity ranged from 24% (April) to 68% (July). Maximum rainfall (86%) occurred in the rainy period during the months of July to October. On the basis, the year can be divided into three seasons, namely rainy (July tc October), winter (November to February) and summer (March to June).

Three crops are grown in a year: May to July (Maize), August to October (Paddy) and November to April (Wheat). The cropland fields are under manual tillage in the shallow layers of soil (5 cm). The croplands are highly productive, resource rich (water and nitrogen input from irrigation and cattle) and experience a fair amount of disturbance due to human activities throughout the growing season.

For the estimation of plant biomass, a total of 5 quadrats (50 cm × 50 cm) were harvested each month. Aboveground net primary production was determined by the trough analysis method for live plus recent dead plant material (Singh *et al.*, 1975). According to this method the sum of successive positive changes in the live biomass and the sum of positive changes in the standing dead biomass, which occurred concurrently with the live biomass, were totalled.

The population density of insects was studied using the removal trapping method. For the purpose, a cage with an area of 1 $m^2$ was constructed which has an entrance of 80 cm × 80 cm on one side, 10 cm above the ground level. Wire-gauze of 5 meshes per cm was fixed on all the sides of the cage except on the ground surface. The size of the wire-gauze prevented escape of captured insects from the cage. Sampling from 5 different areas at 15 days interval was done, ensuring that the cage did not disturb the tip of the vegetation. The trapped insects were killed in jars containing ethyl acetate. The collected insects were oven-dried at 60 °C for 24 h. Each specimen was weighed with the pin in a single pan electronic balance (0.01 mg accuracy) for biomass estimation. The insects were separated into species and individuals occupying different trophic levels i.e., herbivores, omnivores, saprophages, parasites and predators.

Secondary net production was calculated following Wiegert's (1965) method. Species diversity $H'(P)$ was calculated using Shanon and Wiener (1963) expression. Impact of herbivores on vegetation was calculated using weight-specific consumption (Kaushal and Joshi, 1991) and the time series biomass data determined in the field. Total annual consumption was obtained by totalling the consumption of all seasons calculated as $C_s = B \times N \times C_w$, where, $C_s$ is the seasonal consumption, $B$ is the mean seasonal biomass and is calculated using Petrusewicz and Macfadyen (1970) expression.

## RESULTS AND DISCUSSION

### Primary production

A total of 54 species were recorded in the cropland. Live shoot of 49 species were present in the rainy season, 26 in the winter and 41 in the summer season.

The live shoot biomass was maximum during the rainy season in both years, and then declined during the winter season. No crop was grown during December 2006 to February 2007. Both live shoot (650.4 g $m^{-2}$) and dead shoot biomass (52.6 g $m^{-2}$) were higher in the first year than during second year, which was 341.5 g $m^{-2}$ and 39.5 g $m^{-2}$, respectively. It was because of more rainfall (1790 mm) in the first year than (1011 mm) in the second year. The aboveground net primary production was also higher (2896 kJ $m^{-2}$ $yr^{-1}$) in the first year 2006 than in the second year (2166 kJ $m^{-2}$ $yr^{-1}$).

### Species richness and trophic components

A total of 88 species belonging to 9 insect orders and 33 families were collected of which 40 were recorded in both years. Table 3 lists the total number of species and individuals of different orders collected.

Species richness was higher in summer (26 species) and rainy season (34 species) than in winter (23 species). Species richness was significantly positively correlated with minimum temperature ($r = 0.335$; $P \ll 0.05, df = 24$), maximum temperature ($r = 0.464$; $P < 0.05, df = 24$), and live shoot ($r = 0.414$; $P < 0.05, df = 24$).

On the basis of number of species collected, 59.9% were herbivores, 31.5% predators, 4.7% parasites and 3.9% omnivores; on the basis of number of individuals, 61.5% were herbivores, 33.2% predators, 1.2% parasites and 4.1% omnivores; and on the basis of biomass, 75.4% were herbivores, 22% predators, 0.3% parasites and 2.3% omnivores (Figs. 1a-c).

Boiteau (1983) and Ryszkowski *et al.* (1993) have also reported that herbivores were the dominant insect group in comparison to other tropic levels in agro ecosystems.

Herbivores in all reported habitats and in the present investigation are not limited by the availability of food, and can thus maintain relatively higher abundances, whereas predatory, parasitic and other trophic components of insect communities depend considerably on the existence of refuge habitats. Thus, population or species in all trophic levels are not limited by the abundance of food and by competition for food resources (Sinclair, 1975; Belovsky, 1986).

### Density and biomass

Density ranged from 0 (December) to 7.8 $m^{-2}$ (July) during the study period (Table 1). Maximum number of insects was recorded during the rainy period and the minimum during winter season.

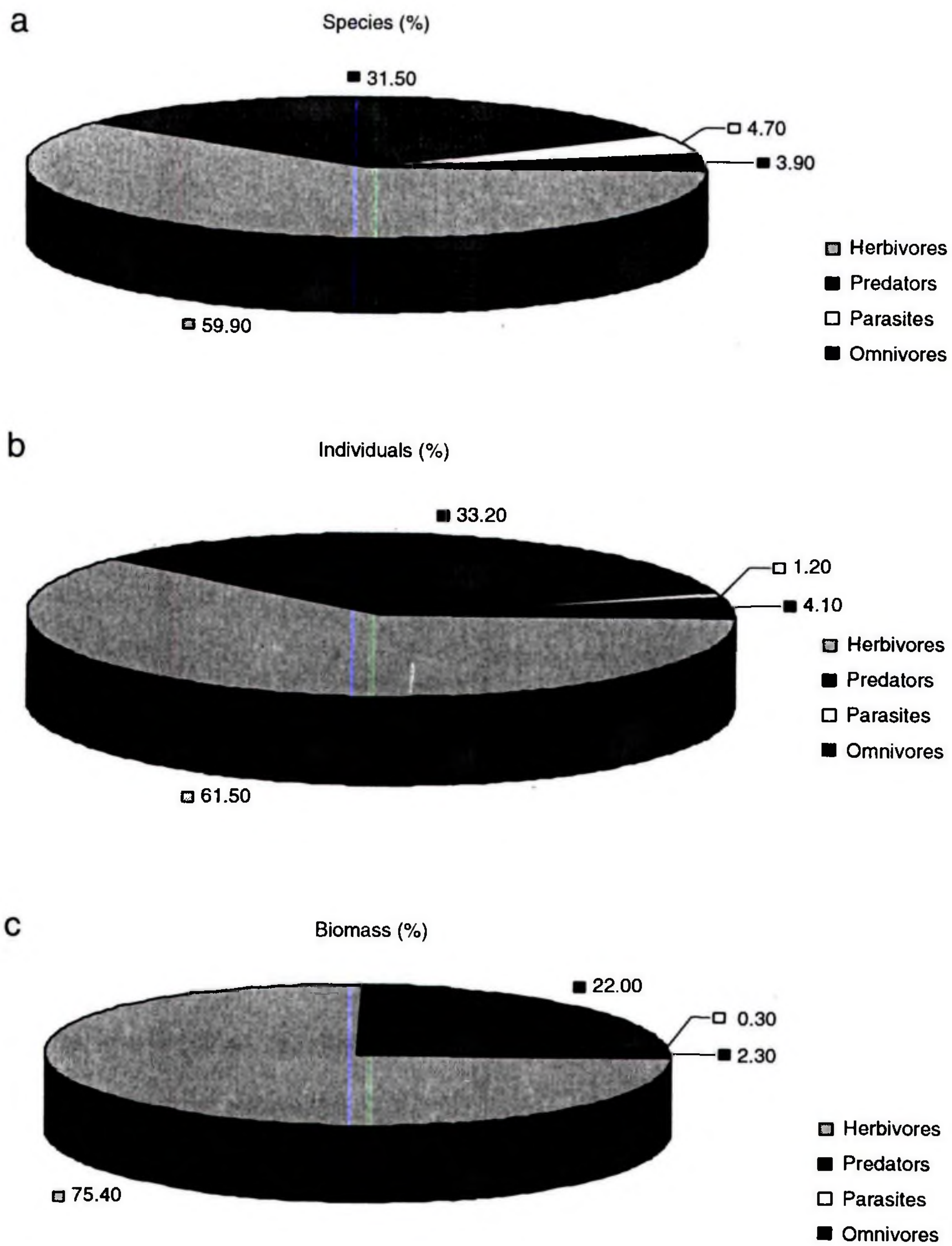


FIGURE 1. The Guild structure of the insect community.

TABLE 1. Ecology parameters of insect population in a cropland of central Himalayan region

| Period of observation | | Density ($m^{-2}$) | | | Biomass ($mg\ m^{-2}$) | | | Species diversity (H') | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2005–06 | 2006–07 | Mean | 2005–06 | 2006–07 | Mean | 2005–06 | 2006–07 | Mean |
| Summer | M | 3.6 | 3.2 | 3.4 | 92.2 | 60.5 | 76.35 | 1.47 | 1.44 | 1.42 |
| | A | 4.7 | 4.9 | 4.8 | 101.6 | 241.8 | 171.7 | 1.44 | 1.44 | 1.42 |
| | M | 4.4 | 2.8 | 3.6 | 121.7 | 123.4 | 122.55 | 1.43 | 1.44 | 1.44 |
| | J | 3.0 | 3.2 | 3.1 | 112.9 | 231.4 | 172.15 | 1.34 | 1.41 | 1.41 |
| | Total | 15.7 | 14.1 | 14.9 | 428.4 | 675.1 | 542.75 | – | – | – |
| Rainy | J | 1.9 | 4.7 | 3.3 | 100.1 | 348.3 | 224.2 | 1.44 | 1.42 | 1.39 |
| | A | 4.2 | 3.8 | 4.0 | 990.3 | 725.1 | 857.7 | 1.38 | 1.41 | 1.36 |
| | S | 5.4 | 2.3 | 3.85 | 547.8 | 99.1 | 323.45 | 1.44 | 1.36 | 1.43 |
| | O | 5.7 | 5.9 | 5.8 | 468.8 | 389.3 | 429.05 | 1.43 | 1.44 | 1.43 |
| | Total | 17.2 | 16.7 | 16.95 | 2107.0 | 1561.8 | 1834.4 | – | – | – |
| Winter | N | 4.3 | 2.5 | 3.4 | 171.6 | 99.7 | 135.65 | 1.44 | 1.42 | 1.44 |
| | D | 2.9 | 0.3 | 1.6 | 128.4 | 3.3 | 65.85 | 1.44 | 1.31 | 1.44 |
| | J | 0.3 | 2.1 | 1.2 | 6.8 | 36.4 | 21.6 | 1.00 | 1.40 | 1.41 |
| | F | 1.3 | 3.2 | 2.25 | 38.8 | 47.1 | 42.95 | 1.40 | 1.42 | 1.39 |
| | Total | 10.8 | 8.1 | 0.45 | 345.6 | 186.5 | 266.05 | 1.39 | 1.41 | 1.42 |
| Grand Total | | 43.7 | 38.9 | 41.3 | 2881.0 | 2423.4 | 2652.2 | | | |

Population density of insects was positively correlated with the maximum temperature ($r = 0.436$; $P \leqslant 0.05, df = 24$), minimum temperature ($r = 0.522$; $P \leqslant 0.01, df = 24$), rainfall ($r = 0.168$; $P \leqslant 0.05, df = 24$), and live shoot ($r = 0.489$; $P < 0.05, df = 24$).

Extremely low and high temperature, rainfall and vegetation cover have been reported to influence the population density of insects (Thomas *et al.*, 1998).

Biomass of insects ranged from 0 (December) to 1456.4 mg m$^{-2}$ (August). Biomass was significantly and positively correlated with density ($r = 0.591$; $P \leqslant 0.01, df = 24$).

The biomass estimation of different trophic levels is of particular importance in analyzing predator-prey relationships. A highly significant positive correlation ($r = 0.286$; $P < 0.05, df = 48$) was found between the biomass of predators and their potential prey (herbivores).

## Species and trophic level diversity

The Shanon-Wiener index H′ varied from 1.36 to 1.44 (Table 1). Monthly fluctuations recorded during two years are due to the changes in the numerical importance of same of the species.

Human disturbances such as grazing, ploughing and logging (You and Li, 2006), predatory insects (Boiteau, 1983) and cutting of vegetation (Morris and Plant, 1983) and monocropping pattern (Gadakar *et al.*, 1990) result in serious degeneration of the environment and reduction in the species diversity in different land use systems.

Herbivores had higher species richness and had greater abundance than all other trophic levels in the present study. Herbivore diversity (1.27) was almost similar to enemy diversity i.e. predators and parasitoids (1.28).

The indirect effects of plant and enemy diversity on other levels either decreases (Dyer and Letourneau, 2003) or increases (Paine, 1966) the herbivore diversity, depending on the competitive position of the species. Our results support Dyer and Letourneau (2003) contentions.

## Secondary net production

The tissue production estimates of herbivores in the present study is based on the calculations of the mean biomass of herbivores on each sampling date during 2005–2007. Cumulative net secondary production was 7016.8 mg m$^{-2}$ yr$^{-1}$ in first year (157.2 kJ m$^{-2}$ yr$^{-1}$) when converted to joules by multiplying with 22 Jmg$^{-1}$ (Kaushal and Joshi, 1991) 6162.9 mg m$^{-2}$ yr$^{-1}$ in second year (138 kJ m$^{-2}$ yr$^{-1}$). Mean secondary production was 6589.9 mg m$^{-2}$ yr$^{-1}$ (147.6 kJ m$^{-2}$ yr$^{-1}$). In the present study, as a proportion of net primary production, secondary production was 5.8%. Secondary net production values recorded in the present study fall in the range of 2.67–3407 kJ m$^{-2}$ for herbivores in different habitats (Blummer and Diemer, 1996;

TABLE 2. Seasonal and annual consumption (kJ $m^{-2}$ $yr^{-1}$) by herbivores from March 2005 to February 2007

| Season | No. of days | Mean biomass (mg $insect^{-1}$) | Consumption (KJ $m^{-2}$) |
|---|---|---|---|
| *March 2005 to February 2006* | | | |
| Summer (March–June) | 122 | 31.1* × 22.4** × 0.302*** | 25.7 |
| Rainy (July–October) | 123 | 153.6 × 22.4 × 0.302 | 127.8 |
| Winter (November–February) | 120 | 50.2 × 22.4 × 0.302 | 40.8 |
| Total (KJ $m^{-2}$ $yr^{-1}$) | | | 194.3 |
| *March 2006 to February 2007* | | | |
| Summer (March–June) | 122 | 56.4 × 22.4 × 0.302 | 46.5 |
| Rainy (July-October) | 123 | 112.3 × 22.4 × 0.302 | 93.4 |
| Winter (November–February) | 120 | 27.9 × 22.4 × 0.302 | 22.6 |
| Total (KJ $m^{-2}$ $yr^{-1}$) | | | 162.5 |
| Average consumption (KJ $m^{-2}$ $yr^{-1}$) (during March 2005–February 2007) | | | 178.4 |

*Mean biomass calculated from field data; ** Energy values (22.4 J $mg^{-1}$) considered after Kaushal and Vats (1984); ***Weight-specific consumption (0.302 J $insect^{-1}$) after Kaushal and Joshi (1991).

Tewari *et al.*, 2006). Low secondary production of herbivores (147.6 kJ $m^{-2}$ $yr^{-1}$) in the present study could be attributed to low population density of insects.

As a proportion of net primary production, secondary production was 5.8%, which is higher than the reported values of 0.006 to 3% (Blummer and Diemer, 1996) suggesting that herbivores are not food limited.

## Insect herbivory

The effect of herbivores on plant production is usually estimated from the amount of plant biomass that is consumed by herbivores and is expressed is weight or energy units.

On the basis of weight-specific consumption (Kaushal and Joshi, 1991), total consumption by herbivores in the cropland was 194.3 kJ $m^{-2}$ $yr^{-1}$ in first year, and 162.5 kJ $m^{-2}$ $yr^{-2}$ in second year. Average consumption by herbivores during 2005–2007 was 178.4 kJ $m^{-2}$ $yr^{-1}$ (Table 2). Herbivores, thus utilized 7% of the net primary productivity.

Impact of herbivores on net primary production in the present investigation fall in the range of reported values of 1 to 30% with an average of 6% (Wiegert and Petersen, 1983).

TABLE 3. Species composition of different insect orders recorded from March 2005 to February 2007 in the cropland

| Ser No. | Taxon | Mean No. of individuals | Ser No. | Taxon | Mean No. of individuals |
|---|---|---|---|---|---|
| | COLEOPTERA (1) | | 22. | *Lasiopticus sclaniticus* Meig. | 1.5 |
| | **Chrysomelidae (1)** | | | Unidentified | 5.5 |
| 1. | *Aulacophora foveicollis* Lucas | 5.0 | | **Tipulidae (10)** | |
| 2. | *Haltica cyanea* Weber | 0.5 | 23. | *Tipula* sp. | 0.5 |
| 3. | *Laius melleifera* Champion | 4.0 | | **HETEROPTERA (3)** | |
| 4. | *Zygogramma bicotorata* Pallist | 1.5 | | **Coreidae (11)** | |
| | Unidentified | 4.0 | 24. | *Euthochtha galeator* F. | 2.5 |
| | **Carabidae (2)** | | 25. | *Halgomorplia ficus* F. | 0.5 |
| 5. | *Catrassius* sp. | 1.0 | 26. | *Leptocorisa varicornis* F. | 5.5 |
| 6. | *Calosoma* sp. | 0.5 | | Unidentified | 3.0 |
| 7. | *Chlaenias* sp. | 0.5 | | **Pentatomidae (12)** | |
| | **Coccinellidae (3)** | | 27. | *Dolycoris indicus* Stal. | 14.5 |
| 8. | *Adonia variegate* Goeze | 15.0 | 28. | *Palmena spinosa* Dist. | 1.0 |
| 9. | *Coccinella septumpunctata* L. | 23.0 | 29. | *Strachia crucigera* Hahn. | 15.0 |
| 10. | *Coccinella transversalis* F. | 5.0 | | **Pyrrhocoridae (13)** | |
| 11. | *Exochanius* sp. | 0.5 | 30. | *Dysdercus cingulatus* F. | 8.0 |
| 12. | *Henosepilachina vigintioctopunctata* F. | 0.5 | 31. | Nymphs | 5.0 |
| 13. | *Menochilus sexmaculatus* F. | 6.5 | | Unidentified | 1.0 |
| 14. | *Micraspis* sp. | 1.5 | | **HOMOPTERA (4)** | |
| 15. | *Psyllobora bisoctonotata* Mulsant | 1.0 | | **Jassidae (15)** | |
| 16. | *Epilachna territa* Mulsant | 0.5 | 32. | *Goniagnathus* sp. | 0.5 |
| | **Lycidae (4)** | | | **HYMENOPTERA (5)** | |
| | Unidentified | 2.0 | | **Apidae (16)** | |
| | **Meloidae (5)** | | 33. | *Apis cerana* F. | 3.0 |
| 17. | *Mylabris phalerata* Pallas | 28.5 | 34. | *Apis dorsata* Fabr. | 1.0 |
| | **Tenebrionidae (6)** | | 35. | *Apis* sp. | 0.5 |
| 18. | *Gonocephalum depressum* F. | 1.0 | 36. | *Apis mellifera* L. | 25.5 |
| | **DIPTERA (2)** | | | **Eumenidae (17)** | |
| | **Muscidae (7)** | | 37. | *Eumenes ptiolata* F. | 0.5 |
| 19. | *Musca* sp. | 6.6 | | Unidentified | 1.0 |
| | **Asilidae (8)** | | | **Ichneumonidae (19)** | |
| | Unidentified | 1.5 | 38. | *Fileanta* sp. | 0.5 |
| | **Syrphidae (9)** | | 39. | *Microthalma* sp. | 1.0 |
| 20. | *Episyrphes balteatus* De Geer | 16.0 | 40. | *Xanthopinnpla stemmator* Thunb. | 1.0 |
| 21. | *Ischidon scutellaris* Fabr. | 0.5 | 41. | *Xanthopinnpla* sp. | 0.5 |

TABLE 3. Contd.

| Ser No. | Taxon | Mean No. of individuals | Ser No. | Taxon | Mean No. of individuals |
|---|---|---|---|---|---|
| | Unidentified | 1.5 | 68. | *Delias eucharis* Dury | 0.5 |
| | **Sphecidae (20)** | | 69. | *Eurema hecabe* Moore | 0.5 |
| 42. | *Sphex madraspatunum* F. | 0.5 | 70. | *Paseroma valeria* Hippa. | 0.5 |
| | **Vespidae (21)** | | 71. | *Pieris brassicae* Linn. | 13.0 |
| 43. | *Polistes* sp. | 1.0 | 72. | *Pieris* sp. | 0.5 |
| 44. | *Polistes stigma* F. | 4.0 | | **MANTODEA (7)** | |
| 45. | *Vespa cincta* F. | 11.0 | 73. | *Mantis* sp. | 1.0 |
| 46. | *Vespa* sp. | 5.5 | | **ODONATA (8)** | |
| | **Xylocopidae (22)** | | | **Gomphidae (28)** | |
| 47. | *Xylocopa* sp. | 1.5 | 74. | *Sympehum fenscolombae* Seff. | 14.0 |
| | **LEPIDOPTERA (6)** | | | **Libellulidae (29)** | |
| | **Hesperiidae (23)** | | 75. | *Brachythemis contaminate* Fabr. | 0.5 |
| 48. | *Parnara* sp. | 3.0 | 76. | *Diplocodes ncloulosa* F. | 0.5 |
| | **Lycaenidae (24)** | | 77. | *Palpopluera sexmaculata* F. | 0.5 |
| 49. | *Zizeeria* sp. | 6.5 | 78. | *Tristria puluinata* Uvarov | 10.0 |
| | **Nymphalidae (25)** | | | Unidentified | 0.5 |
| 50. | *Acraea violae* Fabr. | 1.0 | | **ORTHOPTERA (9)** | |
| 51. | *Aridne merione* Cramer | 7.0 | | **Acrididae (30)** | |
| 52. | *Danais chrysippus* L. | 2.0 | 79. | *Acrida gigantia* Herbst. | 2.5 |
| 53. | *Danus genutica* Cramer | 0.5 | 80. | *Acrida robusta* Serv. | 5.0 |
| 54. | *Junonia hierta* F. | 0.5 | 81. | *Geonia punctigrons* Stal. | 0.5 |
| 55. | *Junonia lenionias* Linn. | 2.0 | 82. | *Nomadacris septemfasicata* Serv. | 10.0 |
| 56. | *Junonia orithya* Linn. | 1.0 | 83. | *Perella insignis* Bovilar | 0.5 |
| 57. | *Melantis leda* Dury | 1.5 | 84. | *Truxalis nasutus* Linn. | 2.5 |
| 58. | *Neptis hylas* Moore | 0.5 | 85. | *Xenocatntops catantopis humilis* Serv. | 1.0 |
| 59. | *Oyphima* sp. | 4.0 | 86. | Nymphs | 5.5 |
| 60. | *Parantica aglea* Cramer | 0.5 | | Unidentified | 1.0 |
| 61. | *Paploea core* Cramer | 1.5 | | **Gryllidae (31)** | |
| 62. | *Precis iphita* Cramer | 0.5 | 87. | *Brachytrypes orientals* Burm. | 2.0 |
| 63. | *Symbrenthia lilaea khasiana* Moore | 0.5 | | Nymphs | 0.5 |
| | **Papilionidae (26)** | | | **Tettigonidae (32)** | |
| 64. | *Papilio polytes* Linn. | 4.0 | | Unidentified | 1.0 |
| | **Pieridae (27)** | | | **Pyrgomorphidae (33)** | |
| 65. | *Catopsila* sp. | 6.0 | 88. | *Poecilocerus pictus* Fabr. | 0.5 |
| 66. | *Cepora nerissa* F. | 10.0 | | **Total** | **394** |
| 67. | *Colias croceus* F. | 0.5 | | | |

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# Effect of different prey densities on the reproductive attributes of *Harmonia dimidiata* (Fabricius) (Coleoptera: Coccinellidae)

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ABSTRACT: Oak trees are used for rearing eri silk worm by rural folk in several parts of north-east India. The aphid species *Cervaphis quercus* Takahashi is a monophagous pest on these trees during spring and summer and the coccinellid *Harmonia dimidiata* is its dominant predator. Effect of different prey densities on *H. dimidiata* was studied in the laboratory. Female beetles were maintained from the time of eclosion till death at one of fixed densities of 25, 50, 75, 100 or 125 aphids. Both functional response and reproductive numerical response showed upper asymptote at 100 adult aphids/female. At this density, females matured early and produced more eggs over a longer reproductive period. At the higher prey density of 125 aphids, females did not produce more eggs than the asymptote. Results suggested that *H. dimidiata* is an effective predator of *C. quercus* on oak trees and could be exploited as biocontrol agent in the rising phase of aphid population build up. 

KEYWORDS: coccinellid predator, *Harmonia dimidiata*, prey density, reproductive attributes

## INTRODUCTION

Ladybird beetles (Celeoptera: Coccinellidae) are beneficial tools in the biological control of many phytophagous pests such as aphids, diaspids, coccids, adelgids, aleyrodids, pentatomids, thrips and acarids (Hodek and Honek, 1996; Dixon, 2000). Among the prey groups, aphids are regarded as the most severe insect group due to their unique host plant association, high reproductive potential, polymorphism and long range dispersal (Dixon, 1998).

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The aphid *Cervaphis quercus* Takahashi (Homoptera: Aphididae: Greendideinae) is a monophagous species on oak trees *Quercus serrata* Thunberg (Family Fagaceae) which grows abundantly in the foothills of Manipur State, in north east India and extensively used for the rearing of silkworm *Antheraea prolei* Jolly (Lepidoptera: Bombycidae). Colonization by aphids results in curling and yellowing of leaves and even stunted growth of plants. Natural enemies become important for natural regulation of aphid population. The ladybird species *Harmonia dimidiata* (Fabricius) (Celeoptera: Coccinellidae) is an effective predator of *C. quercus* in the field (Singh, 1992). In field, adults of this coccinellid beetle become active at low aphid density and synchronize their aggregation and reproduction with natural population of *C. quercus* (Sharmila *et al.*, 2007)). There is no information regarding its functional and reproductive numerical responses to change in prey density in order to ascertain its biocontrol ability (Agarwala and Bardhanroy, 1999; Omkar and Pervez, 2002; Agarwala *et al.*, 2007).

## MATERIALS AND METHODS

Males and females of *H. dimidiata* collected from oak trees at Regional Tasar Research Station, Manipur, north-east India were kept in ventilated plastic box and offered an excess supply of *C. quercus*. Unmated males of similar age were collected from the stock culture and these were confined with 2-day old females in 1:1 ratio for 4 h to facilitate mating. Gravid *H. dimidiata* females were taken individually in 9 cm petri dishes and exposed to different prey densities (25, 50, 75, 100 or 125 live adult aphids per dish). For each density 10 dishes were set up as replicates. The dishes were maintained in an incubator at 22 ± 1 °C and photoperiod of 16:8 h (L: D). Numbers of aphids eaten (functional response) and eggs produced (reproductive numerical response) by female beetles at different prey densities were noted at 24 h intervals for the entire duration of their life. Percent unviable eggs, pre-ovioposition period, ovioposition period, post-oviposition period, and adult longevity were also determined. Data were subjected to statistical analysis.

## RESULTS AND DISCUSSION

### Functional response and reproductive numerical response

Mean number of aphids eaten and eggs produced by a *H. dimidiata* female per day increased gradually from low to higher prey densities until an upper asymptote was recorded at 100 aphids/female/150 $cm^2$. Prey consumption and eggs production were the least at 50 aphids/female. At 125 aphids/female, prey consumption and egg production were not significantly different from the asymptote. Female beetles did not produce eggs at the density of 25 aphids (Table 1). A number of studies have demonstrated the effect of prey quantity on the feeding, survival and reproduction of aphidophagous predators (Evans and Youssff, 1992; Ives *et al.*, 1993; Yasuda and Ishikawa, 1999; Agarwala *et al.*, 2001). Most of the coccinellid predators, as well as other predators of aphids, are reported to show Holling's (1965) functional response

TABLE 1. Number of aphids eaten, reproductive attributes and adult longevity of *H. dimidiata* females at different prey densities of *Cervaphis quercus*

| Prey density | Aphids eaten/ female/ day | Total no. of eggs produced /female | Progeny loss (%) | Pre-reproductive period (d) | Oviposition period (d) | Adult longevity (d) |
|---|---|---|---|---|---|---|
| 25 | 247.53$^{a}$ | 0$^{a}$ | 0 | 0$^{a}$ | 0$^{a}$ | 25.5$^{a}$ |
| 50 | 587.22$^{b}$ | 637.80$^{b}$ | 2.71 | 14.2$^{b}$ | 22.8$^{b}$ | 43.2$^{b}$ |
| 75 | 1728.64$^{c}$ | 755.80$^{c}$ | 1.64 | 11.2$^{c}$ | 29.2$^{c}$ | 50.9$^{c}$ |
| 100 | 2244.17$^{d}$ | 969.20$^{d}$ | 0.41 | 9.4$^{d}$ | 36.4$^{d}$ | 60.9$^{d}$ |
| 125 | 1934.40$^{e}$ | 846.34$^{d}$ | 1.02 | 10.1$^{d}$ | 31.2$^{d}$ | 54.6$^{d}$ |

Dissimilar letters with values in a column denote significant difference between treatments by Tukey's multiple range test at $P < 0.05$.

type II (Hodek and Honek, 1996; Agarwala *et al.*, 2001). Such a response is typical of predators foraging in unstable prey populations and this means rapid utilization of food by predators even at lower densities. In the present study, *H. dimidiata* females displayed similar response.

## Pre-oviposition period, oviposition period and adult longevity

Females kept at lower prey densities showed longer pre-oviposition period but shorter oviposition period than the females kept at higher prey densities (Table 1). Time taken for maturation of eggs and commencement of egg laying was the lowest at 100 aphids/female/150 cm$^2$ and this was not significantly different from the pre-oviposition period of females kept at 125 aphids/female. Females kept at a prey density of 25 aphids/female did not produce eggs. Female maintained at lower prey densities lived for fewer days than the females kept at higher prey densities. Results of this study revealed a significant influence of prey density on the reproductive attributes of *H. dimidiata* in terms of egg production, reproductive period and number of eggs hatched. Results further suggested that the age of maturity was profoundly affected by the quantity of food eaten by females during pre-reproductive period. Females reared at 100 prey density attained maturity significantly faster than the females kept at lower prey densities. The above findings are similar to those of Agarwala and Bardhanroy (1997); Agarwala *et al.* (2001) wherein decreased consumption due to poor supply of preferred aphid prey resulted in longer pre-reproductive period, longer reproductive period of females, higher fecundity and higher success rate of eggs hatching.

## Progeny loss

The percentage of eggs produced by a female that did not hatch is considered here as percent progeny loss. Females kept at a prey density of 100 aphids showed minimum progeny loss than the females kept at lower or higher prey densities (Table 1). The maximum progeny loss was recorded at 50 aphids/female. Lower prey density might have affected the egg development and consequently higher progeny loss as certain amount of food is reported to be necessary for proper maturation of the ovariole

(Honek, 1980). Ferran *et al.* (1984) also recorded a linear relationship between the weight of food consumed and number of eggs hatched.

Feeding and oviposition patterns of individual predators reflect the adaptiveness of their populations to foraging conditions in fields. Host-plant restricted aphid colonies are often irregularly distributed in space and time (Honek, 1991; Agarwala and Bhattacharya, 1995; Dixon, 1998). As a result, at any instant, number of aphids available per unit area of host plant as food for predators may vary. In such environment, predators capable of adjusting to variable food quantity will cause maximum mortality of prey population. In this study, *H. dimidiata* females displayed similar response.

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# Ant species richness in Chorao Island, Goa, India

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ABSTRACT: Though ants are ubiquitous in distribution, scientific recording of their diversity in various ecological niches, particularly islands, is far from satisfactory. Hence an attempt was made to record ant species richness in Chorao Island of Goa, a coastal island known for considerably rich biodiversity. This island, about 2.1 $km^2$ in area, was found to harbour 38 species of ants belonging to 24 genera and six subfamilies. 

KEYWORDS: ant species richness, Chorao Island, Goa

## INTRODUCTION

Ants are ubiquitous insects present in all terrestrial habitats. Their distribution and abundance are greatly influenced by altitudinal and vegetational gradients. A large number of ant species exhibit high adaptability and occupy a wide range of habitats while several species are restricted to specific habitats. There are about 15,000 living ant species estimated from the world, of which 9,000 to 10,000 are described so far (Bolton, 1994). About 500 species have been described from the Indian sub-region by the turn of the 20th century (Bingham, 1903) and since then over 100 species have been added to the Indian ant fauna (Mushtak Ali and Chakravarthy, 2001). Studies on the Indian ant fauna include those of Mushtak Ali (1981, 1991, 1992) in Bangalore and Karnataka State; Gadagkar *et al.* (1993) and Rajagopal *et al.* (1998) in a few selected sites in the Western Ghats; Reddy (1981) in Dharwar; Neena Thak (1995) in the arid zone of Rajasthan; Belavadi *et al.* (1998) in Mudigere representing part of Western Ghats; and Mercy *et al.* (1998) in Chennai. However, lists of ant fauna of islands are still meager, though the Indian mainland is surrounded by clusters of islands of varying sizes and vegetation. In addition to true islands, there are several islands closer along

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the coast. These islands along west coast are particularly interesting since they are almost extensions of Western Ghats and therefore share same ecological history. This study is an attempt to describe the ant fauna of Chorao island in Goa.

## MATERIALS AND METHODS

The study was made at Chorao island of Goa, which measures about 2.1 $km^2$ in area and is surrounded by Mandovi river near Panaji. The area has a network of criss-crossing water channels with tidal variation and has mangrove vegetation (*Rhizophora, Avicennia, Bruguiera, Kandella, Acanthus,* etc.). Other natural vegetation comprises *Anacardium occidentale, Mangifera indica, Bambusa vulgaris, Cocos nucifera, Artocarpus heterophyllus,* etc. Agricultural crops include *Oryza sativa* and *Capsicum annum.* The island has several small human settlements with a population of about 800–1000 contributing to a high level of anthropogenic activity.

Ants were collected from forest, grassland, plantations, mangrove, agricultural areas and human habitation, using standard sampling methods such as bait trap, leaf litter sampling and visual counts. Sampling in each habitat was carried out once in a fortnight between 08.00 h and 16.00 h. A total of 2246 ants from 26 sites within 1.78 $km^2$ area of the island were collected. Ants were preserved in 70% alcohol (Anonymous, 1990) and were identified with the help of standard literature (Bingham, 1903; Holldobler and Wilson, 1990; Bolton, 1994). The identified ants are deposited in Department of Zoology, Goa University, Goa.

## RESULTS AND DISCUSSION

A total of 38 ant species belonging to 24 genera and 6 subfamilies (Table 1) were collected. Myrmicinae were dominant with 16 species, followed by Formicinae with 14 species. The remaining species were under the sub-families Ponerinae (4 spp.), Dolichoderinae (2 spp.), Pseudomyrmicinae (1 sp.) and Aenictinae (1 sp.). The high level of species richness for Myrmicinae and Foramicinae is not surprising since these two sub-families are the most speciose and widely distributed (Holldobler and Wilson, 1990). The total number of species available in the island will be far greater than recorded in this survey since our sampling intensity and area coverage were limited.

The plantation and forest habitats showed highest number of species, 30 and 26, respectively. The grassland had 24 species, while 23 species were recorded in human habitation and 18, in cultivated lands. Only five species could be collected from the mangroves. The richness of the species in plantation and forest habitats can be attributed to heterogeneity of the habitat which improved the availability of nesting sites and food. The richness of ants *Solenopsis* spp,, *Monomorium* spp., *Componotus* spp., and dolichoderines, near human habitation may be attributed to their scavenging habitats. The scarcity of ant species in the mangrove ecosystem may be attributed to constant perturbation by changes in tides resulting in alternating flooding with saline and freshwaters. Out of five species recorded from the mangroves, three species construct arboreal nests, while the other two nest in sites on ground and in tree holes.

TABLE 1. Checklist of ant fauna of Chorao Island, Goa

| Sl.No. | Identity (subfamily, genus and species) | Habitat* |
|---|---|---|
| | **AENICTINAE** | |
| 1 | *Aenictus laeviceps* Smith | F, G, P, A, H |
| | **DOLICHODERINAE** | |
| 2 | *Tainoma melanocephalum* Fabricius | P, H |
| 3 | *Technomyrmex albipes* Smith | P, H |
| | **FORAMICINAE** | |
| 4 | *Anoplolepis gracilipes* (F.Smith) | P, A, G, H |
| 5 | *Camponotus compressus* Jerdon | F, G, P, A, H |
| 6 | *C. angusticollis* Jerdon | F, G, P, A, H |
| 7 | *C. parius* Fabricius | F, G, P, A, H |
| 8 | *C. radiatus* Emeri | F, G, P, A, H |
| 9 | *C. sericius* Forel | F, G, P, H |
| 19 | *Camponotus* sp. Nr. *saundarsi* Emeri | M |
| 11 | *Camponotus* sp.1 | H, P |
| 12 | *Camponotus* sp.2 | P |
| 13 | *Oecophylla smaragdina* Fabricius | F, P, M |
| 14 | *Paratrechian longicornis* Latreille | G, P, A |
| 15 | *Polyrhachis tibialis* Forel | F |
| 16 | *Prenolepis* sp. *Nr. naoroji* Forel | F, G, P, A, H |
| 17 | *P. indica* Forel | M |
| | **MYRMICINAE** | |
| 18 | *Apahenogaster beccarrii* Emery | P, G |
| 19 | *Cataulocus latus* Forel | P, H |
| 20 | *Crematogaster rogenhoferi* Mayr | F, G, P, A, H, M |
| 21 | *Crematogaster* sp. | F, G, P, A, H |
| 22 | *Meranoplus bicolor* Guerin | F, G, P, A, H |
| 23 | *Monomorium criniceps* Mayr | F |
| 24 | *M. gracillimum* Smith | F, G, P, A, H |
| 25 | *M. latinode* Mayr | F, G, P, A, H |
| 26 | *M. scabriceps* May r | F, P |
| 27 | *Myrmicaria brunnea* Saunders | M |
| 28 | *Solenopsis geminate* Fabricius | F, G, P, A, H |
| 29 | *Pheidologeton diversus* Jerdon | F, G |
| 30 | *Pheidole parva* Mayr | M |
| 31 | *Pheidole* sp.1 | F, G, P, A, H |
| 32 | *Pheidole* sp.2 | F |
| 33 | *Tetramorium* sp. *Nr. mixrum* Forel | F, P, H |
| | **PONERINAE** | |
| 34 | *Diacamma rugosum* Le Guillou | F, G |
| 35 | *Leptogenys diminuta* Smith | F, G, P, A, H |
| 36 | *Leptogenys* sp.1 | F, G, A, H |
| 37 | *Pachychondyla tesserinoda* Emery | F, P |
| | **PSEUDOMYRMICINAE** | |
| 38 | *Tetraponera rufonigra* Jerdon | F, G, P, A, H |

*F, Forest; G, Grassland; P, Plantation; A, Agriculture; H, Human habitation; M, Mangrove

The ant fauna of Chorao Island did not reveal any endemic species or species with specific habitat requirements, probably because the habitats encountered are ephemeral in nature. The findings constitute the first step towards development of regional inventories of ants in the west coast of India.

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# A new species of *Brachycyrtus* Kriechbaumer (Hymenoptera: Ichneumonidae) from Karnataka, India

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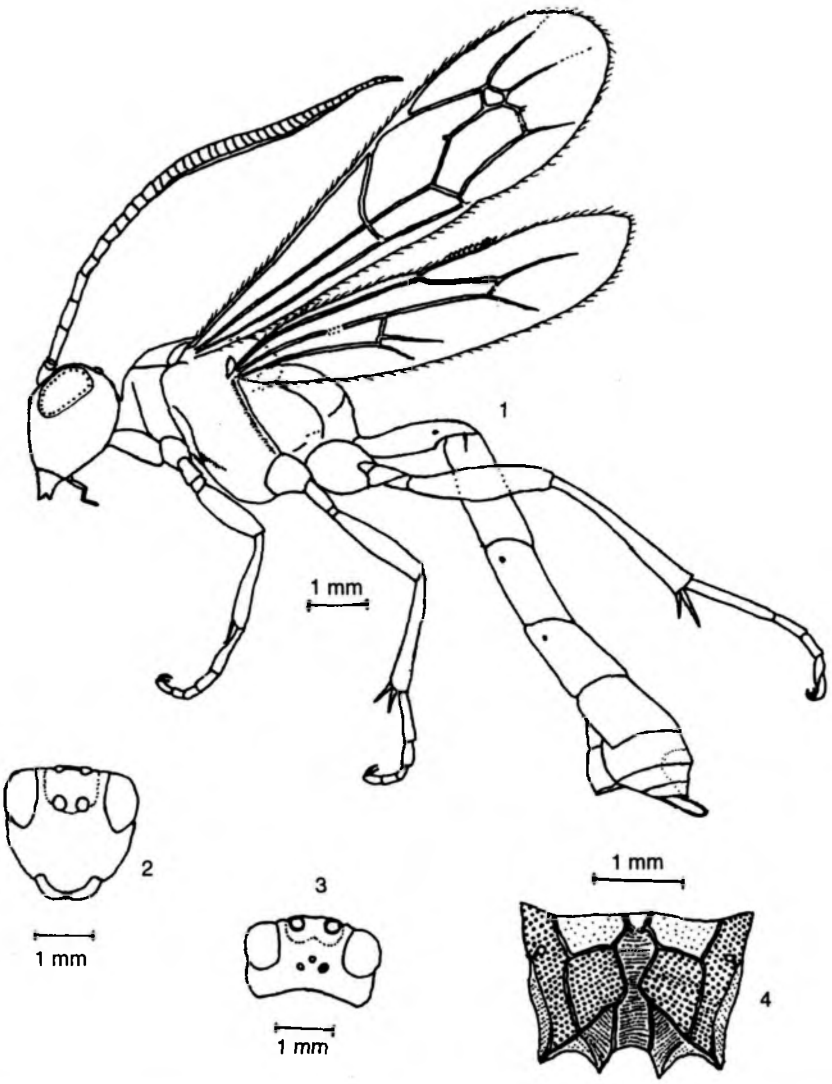
ABSTRACT: A new species *Brachycyrtus sinui*, sp. nov. is described from Karnataka, India. This species can be distinguished from the only other known Indian species, *B. eublemmae* (Rao) by the combination of the following characters: antenna with 45 segments, propodeum with a distinct areola, with well defined longitudinal carinae, wings with a fuscous tinge, first three abdominal tergites reddish orange without any apical band and mesonotum reddish orange without any black marks.


KEYWORDS: Ichneumonidae, *Brachycyrtus sinui*, new species, India

## INTRODUCTION

Ichneumonidae is the largest family of the Order Hymenoptera, with an estimated 60,000 species (Townes, 1969; Yu *et al.*, 2005). The genus *Brachycyrtus*, erected by Kriechbaumer (1880) with *B. ornatus* as type species, belongs to the subfamily Labeninae, tribe Brachycyrtini. The genus has worldwide distribution but most species have been recorded from the Neotropics. The genus is represented in the Indo-Australian Region by five species, of which only one species, *B. eublemmae* (Rao), has been recorded from India (Gupta, 1987). This species is parasitic on *Eublemma silicula*? and *Chrysopa* sp. on lac (Gupta, 1987; Yu *et al.*, 2005). The taxonomy of species of this genus has been covered by Roman (1915); Rao (1953); Walkley (1956); Townes *et al.* (1961); Townes (1969); Gauld (1984) and Gupta (1987). A new species, *B. sinui* sp. nov., from Karnataka, India, is described in this paper. The type specimens are deposited in the Western Ghats Regional Station of the Zoological Survey of India, Kozhikode, Kerala (ZSIK).




FIGURES 1–4. *Brachycyrtus sinui*, sp. nov. – Female: 1, Body profile; 2, Head - front view; 3, Head - dorsal view; 4, Propodeum

### *Brachycyrtus sinui* sp. nov. (Figs. 1–4)

#### Female

Body length including ovipositor 15.75 mm. Body covered with fine, white, short pubescence, hairs on mesonotum and wings brown.

### *Head*

HW 2.42 mm and HL 1.3 mm in dorsal view (Fig. 3); HW 2.42 mm and HL 2.25 mm in front view (Fig. 2); face closely and strongly punctate; clypeus with shallow punctures, interstices smooth, smooth towards apex, apex slightly convex; antennal toruli joined by carina on upper face; malar space 1.75 × basal width of mandible, 1.3 × length of eye in lateral view; mandible with strong, evenly distributed punctures, smooth at apex; upper tooth distinctly longer than lower tooth; labial palp 4 segmented; maxillary palp 5 segmented; frons, vertex and temple with strong, evenly distributed punctures, interstices smooth; antennal scrobe smooth; interocellar distance 1.14 × ocellocular distance, 2.7 × distance between median and lateral ocelli; occipital carina complete, evenly arched, joining hypostomal carina at basad of mandible; antenna (Fig. 1) with 45 segments, flattened in middle (from 14th–36th segments); scape 2.0 × as long as its maximum width, 6.0 × as long as pedicel; pedicel 0.13 × as long as first flagellar segment; first flagellar segment 3.0 × as long as its width, 1.25 × as long as second flagellar segment, 3.0 × as long as last flagellar segment; second flagellar segment 1.0 × as long as third flagellar segment, 2.4 × as long as last flagellar segment; 24th–26th segments 2.0 × as long as its width.

### *Thorax*

3.13 × as long as width between tegulae; pronotum with strong punctures on upper part, smooth in middle, lower part with rugosities; epomia distinct; mesoscutum and scutellum with close, strong punctures; notauli absent; lateral carina of scutellum extending its entire length; metascutellum rugose; mesopleurum and metapleurum with close, strong punctures; prepectal carina extending 0.56 × length of mesopleurum; mesopleural pit distinct; juxtacoxal carina present; propodeum as in Fig. 4; basal and apical transverse carina distinct; spiracle oval, joined to lateral longitudinal carinae by a strong carina; FWL 9.25 mm; FWW 2.5 mm; HWL 7.5 mm; HWW 1.7 mm; areolet pentagonal; nervulus apicad of basal vein; hind wing with two basal and ten apical hamuli; nervellus intercepted distinctly below middle; legs with close shallow punctures.

### *Abdomen*

First tergite 2.09 × as long as its apical width, 0.92 × as long as second tergite, largely smooth at base, apex wide with scattered punctures; second tergite 1.47 × as long as third tergite; second and following tergites with closely arranged shallow punctures; ovipositor pointed, 0.5 × as long as hind femur.

### *Colour*

Largely reddish orange except following markings: ocellar triangle, mandibular teeth, apices of hind femur and hind tibia, fifth (except basolaterally) and following abdominal tergites, ovipositor sheath, extreme apex of first and second hind tarsal segments and third to fifth hind tarsal segments dorsally black; a small dorsomedian

patch on fifth tergite posteriorly, sixth and following tergites dorsomedially white; wings with a fuscous tinge; wing veins dark brown; antennal segments 15th to apex dark brown; basal antennal segments reddish orange to brown.

### Male

Similar to female in sculpture and colour, except fifth abdominal tergite reddish orange (concolourous to body).

### Host

Unknown

### Biology

Unknown

### Etymology

The species epithet is after the name of the collector of the specimen, Mr. P. A. Sinu.

### Distribution

India (Karnataka)

### Material examined

*Holotype*

F, INDIA: Karnataka, Sringeri (13°25′N 75°15′E, ~ 750m ASL), Coll. P. A. Sinu, 15.x.2003. *Paratypes*: 1M & 1F, same data as holotype except date 11.x.2003 & 10.ix.2004 (All specimens deposited at ZSIK).

## DISCUSSION

This new species differs from *B. eublemmae* (Rao) in having (1) antenna with 45 segments (in *B. eublemmae* (Rao) antenna with 27 segments); (2) first three abdominal tergites reddish orange without any apical band (in *B. eublemmae* (Rao) first three abdominal tergites with white apical band); (3) propodeum with a distinct areola, with well defined longitudinal carinae (propodeum without an areola and with a very short longitudinal carina in *B. eublemmae* (Rao)); (4) wings with a fuscous tinge (in *B. eublemmae* (Rao) wings hyaline) and (5) mesonotum reddish orange without any black marks (in *B. eublemmae* (Rao) mesonotum yellow with three long black marks).

*Abbreviations*

HL, Head Length; HW, Head Width; FWL, Fore Wing Length; FWW, Fore Wing Width; HWL, Hind Wing Length; HWW, Hind Wing Width; ZSIK, Western Ghats Regional Station of the Zoological Survey of India, Kozhikode, Kerala, India.

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# A new species and a hitherto unknown alate of Greenideine aphids (Hemiptera: Aphididae) from Kumaon range of Western Himalaya, India

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ABSTRACT: *Eutrichosiphum kumaoni* n.sp. infesting *Castanopsis* sp. and hitherto unknown alate viviparous female of *Eutrichosiphum haldari* Maity and Chakrabarti infesting *Quercus incana* in Kumaon range of Western Himalaya are described.


KEYWORDS: new species, unknown morph, aphids, Western Himalaya

## INTRODUCTION

During a recent survey in the Kumaon range of Western Himalaya, a new species of *Eutrichosiphum* and hitherto unknown morph of *Eutrichosiphum haldari* Maity and Chakrabarti have been collected and described in this paper. The type materials of the new species are presently deposited in the collection of Biosystematics Research Unit, Department of Zoology, University of Kalyani, India.

### *Eutrichosiphum kumaoni* n. sp.

### Apterous viviparous female (Figs. 1–4)

Body 2.22–2.29 mm long and 1.10–1.22 mm as maximum width. Head pale brown, smooth with 1 pair of frontal, 3 pairs of anterior discal and 3 pairs of posterior discal hairs; dorsal hairs long with furcated apices, longest frontal hair 12–13$\mu$m long and 3.60–3.70$\times$ b.d.III. Antennae 6-segmented, 1.34–1.44 mm long, 0.60-0.61$\times$ body; basal 0.60 part of segment III almost smooth, rest of the flagellum gradually and more distinctly imbricated apicad; p.t. 0.21–0.25 mm long and 1.20–1.40$\times$ the base of segment VI and 0.50–0.52$\times$ the segment III; antennal hairs long with acuminate apices, mostly arranged on the inner margin of the segments; longest hair

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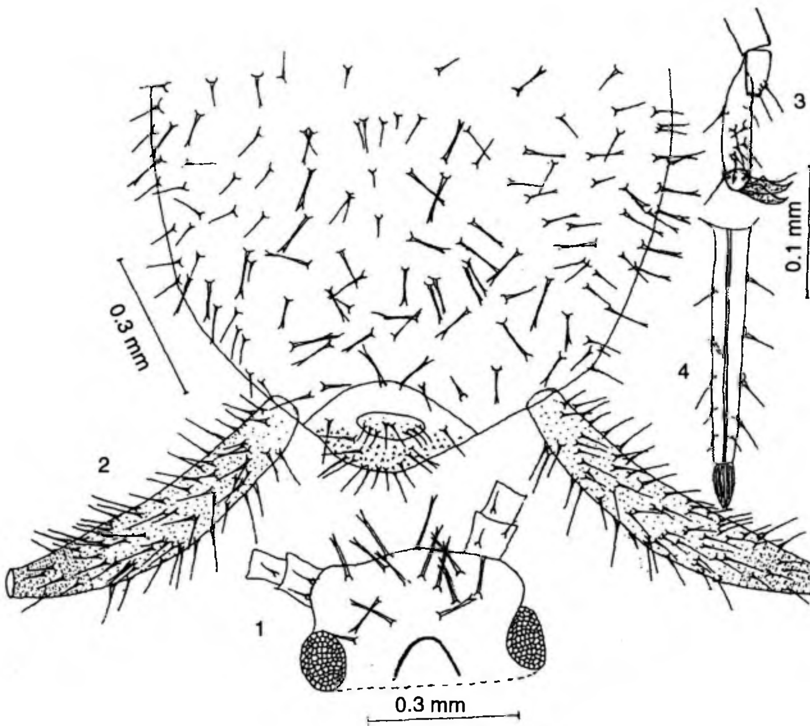



FIGURES 1–4. *Eutrichosiphum kumaoni*, apterous viviparous female: 1, head; 2, Abdomen; 3, h.t.2; 4, u.r.s.

on segment III 9–10$\mu$m long and 2.60–2.70× the b.d.III. Rostrum reaching upto midthoracic segment; u.r.s. slender and acute, 0.22–0.23 mm long and 2.10–2.20× the h.t.2 and with 10 accessory hairs. Thorax dorsally smooth, with few sparse spinules on the margins ventrally, particularly on the mesothorax. Dorsum of abdomen pale, smooth and with both long and short hairs; longer hairs on anterior tergites mostly with furcated apices and 0.09 mm long and 2.60× b.d.III; shorter hairs with acute apices, 4–5 $\mu$m long, 1.50–1.60× b.d.III; anterior tergites each with about 14 hairs, those on tergite 3 about 8–9 $\mu$m long and 2.60–2.70× the b.d.III, tergites 7 and 8 each with 4 and 2 hairs, 10–11 $\mu$m and 9–11 $\mu$m long, 3.00–3.10 and 2.80–3.10× the b.d.III respectively. Venter smooth. Siphunculi gently curved outwards and with sparsely distributed spinules except apical 0.16 portion which is gradually densely spinulose apicad, 0.30–0.36× the body, 1.70–1.80× the width of head across the eyes and 5.50–5.90× its maximum width; width at base 3.10–3.70×, at middle 4.60–5.50× and at apex 3.80–4.20× the width of the hind tibiae respectively. Cauda oval with 6–8 hairs. Genital plate with 12–16 hairs. Legs concolourous with head; femora smooth. F.T.C. 7,7,7.

*Measurments of holotype in mm:* Body length 2.22, width 1.10; antenna 1.34; antennal Segments III: IV: V: VI 0.41:0.18:0.21:(0.16 + 0.21); u.r.s 0.23; h.t.2 0.10; siphunculus 0.29; cauda 0.04.

**Alate viviparous female (Figs. 5–8)**

Body 2.54 mm long and 0.78 mm as maximum width. Head dark brown, smooth, dorsal hairs long with acuminate apices, with 1 pair of frontal, 6 anterior discal and 7 posterior discal hairs; longest frontal hair 11 $\mu$m long, 5.0× the b.d. III; Antenna dark brown, 6-segmented, 1.58 mm long and 0.60× the body; segment III almost smooth and with 11-14 almost round secondary rhinaria; primary rhinaria ciliated; p.t. 0.28 mm long and 1.50× the base of segment VI, 0.50× antennal segment III; longest hair on segment III 10 $\mu$m long and 4.50× b.d.III. U.R.S. slender and acuminate, 0.18 mm long and with 8 accessory hairs. Dorsum of abdomen brown, wrinkled and with segmental dark brown spino-pleural bands and marginal patches, those on segments 3–5 coalesce medially to form a median patch leaving some segmental gaps marginally; these bands on segments 6–8 also fuse to form another median patch; dorsal hairs long and acute; longest hair on tergite 3 about 8 $\mu$m long and 3.50× b.d.III; tergites1and 2 each with 14 hairs, segment 3 with 10, segment 4 with 10, segment 5 with 8, segment 6 with 6 and segment 7 and 8 each with 2 hairs respectively. Venter sparsely spinulose. Siphunculi dark brown, long and reticulated throughout, 0.94 mm long and 0.30× body, siphunculi at base 2.60×, at middle 3.10× and at apex 2.80× the width of the hind tibiae respectively. Genital plate with 20 hairs. Cauda obtusely conical with 8 hairs. Other characters as in apterous viviparous females.

*Measurements of the specimen in mm:* Body length 2.54, width 0.78; antenna 1.58; antennal segments III:IV:V:VI 0.21:0.23:0.18:(0.28+0.19); u.r.s.0.18; h.t.2 0.42; siphunculus 0.30; cauda 0.03.

*Type material*

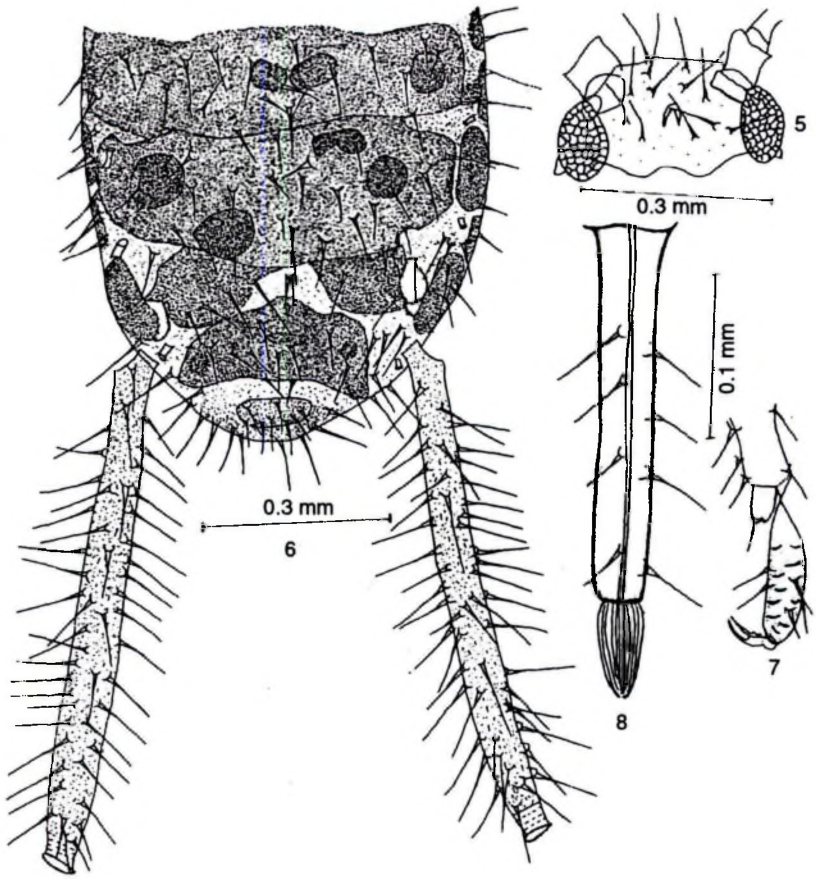
Holotype: Apterous viviparous female ex. *Castanopsis* sp., Kousani, Kumaon, Uttaranchal, India, 03.x.2006, Coll. S. Chakrabarti (coll.no. 6533). Paratypes: 4 apterous viviparous females, 1 alate viviparous female and 2 nymphs with the collection data same as for the holotype.

*Note*

Apterae yellowish, alate blackish and nymph green in life. These are found on the under surface of young leaves.

*Remarks*

This new species in lacking spinules on head and abdomen, most of the dorsal hairs with furcated apices and acute u.r.s. comes close to *Eutrichosiphum atini* Chatterjee and Raychaudhuri (1977). However, it differs from *atini* in having pale head, abdomen




FIGURES 5–8. *Eutrichosiphum kumaoni*, alate viviparous female: 5, head; 6, abdomen; 7, h.t.2; 8, u.r.s.

and siphunculi (dark and sclerotised in *atini*). In addition, siphunculi in *atini* bear furcated hairs. This new species in having pale body including siphunculi is also close to *E. pallidum* Noordam (1994) but the latter species has 5-segmented antennae and spinules on venter of abdomen.

So far 10 species of *Eutrichosiphum* are known to infest *Castanopsis* spp. These include *dubium* v.d.Goot, *flavum* Takahashi, *tatakanum* (Takahashi), *neotattakanum* Agarwala and Ghosh, *pseudopasaniae* Szelegiewicz and *russellae* Ghosh, Ghosh and Raychaudhuri from India (in Ghosh and Agarwala, 1993) and *nigrum* Noordam, *pasaniae* (Okajima), *pullum* Noordam and *sinense* Raychaudhuri from elsewhere (in Noordam, 1994; Takahashi, 1962). *Eutrichosiphum kumaoni* n.sp. differs from all these species in having pale body including siphunculi (in the above species body

is sclerotized and brown to dark brown in colour and head and venter of abdomen with spinules).

*Etymology*

The species is named after the Kumaon range of the Himalaya wherefrom it has been collected.

### ***Greenidea (Trichosiphum) haldari*** **Maity & Chakrabarti**

**Alate viviparous female (Figs. 9–11):**

Body elongated, 2.43 mm long and 1.35 mm as maximum width. Head brown, smooth, with 1 pair of frontal, 7 anterior discal and 4 posterior discal hairs. Antennae smooth, 6-segmented; segments I–IV dark brown, rest somewhat pale; flagellum imbricated, flagellar hair short with acute or acuminate apices; longest hair on segment III 11 $\mu$m long and 3.12× the b.d.III; p.t. 0.29 mm long and 1.55× the base of segment VI and 0.54× the segment III; primary rhinaria round, segment III with 17 elongate and segment V with 1 round secondary rhinaria. Rostrum reaching upto metathoracic segment; u.r.s. 0.23 mm long and 2.0× h.t.2; segment 4 bearing 10 accessory hairs. Dorsum of abdomen wrinkled and brown; dorsal hairs long with acuminate apices; longest hair on abdominal segment 3 about 0.07 $\mu$m long and 5.0× the b.d.III; tergites 7 and 8 each with 2 long hairs with pointed apices; longest hair on tergite 8 about 10 $\mu$m long and 3.12× b.d.III and segment 7 with 10 $\mu$m long and 2.81× b.d.III. Venter of abdomen with some scattered marginal spinules. Siphunculi dark brown, reticulated and slightly curved at apex, 1.12 mm long and 0.44× the body and 9.20× as its maximum width, 1.96× the width of head across the eyes, at base 3.60×, at middle 4.60× and at apex 2.30× the width of hind tibiae respectively. Cauda with a distinct median stylus, bearing 8 hairs. Genital plate densely spinulose on posterior half with 28 hairs. Legs dark brown; femora and tibiae smooth. F.T.C. 6,6,6. Other characters as in apterous viviparous females.

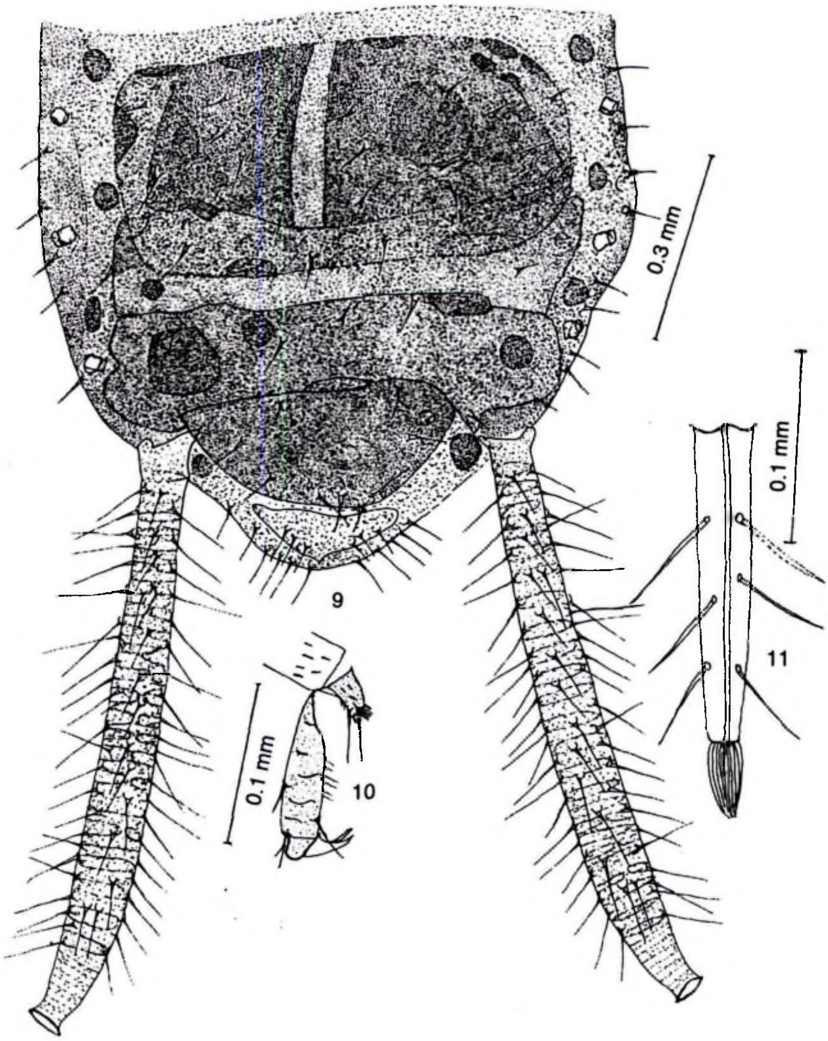
*Measurements of one speciemen in mm:* Body length 2.52, width 1.12; antenna 1.31; antennal segments III:IV:V:VI 0.53:0.22:0.21:(0.18+0.29); u.r.s. 0.23; h.t.2 0.11; siphunculus 1.12; cauda 0.03.

*Specimens studied*

4 apterous viviparous females, 1 alate viviparous female, 3 alatoid nymphs from *Quercus incana*, Kousani, Kumaon, Uttaranchal, India, 03.x.2006, Coll. S. Chakrabarti (coll. no 6534).

*Note*

Apterae black in life, found on the buds and under surface of leaves.




FIGURES 9–11. *Greenidea (Trichosiphum) haldari*, alate viviparous female: 9, abdomen; 10, h.t.2; 11, u.r.s.

## *Remarks*

This species was originally described by Maity and Chakrabarti (1980) from Mussorie, Western Himalaya infesting *Quercus incana*. Since then it was known by its apterous viviparous female only. Hitherto alate viviparous female is described here for the first time.

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# Effect of *Vinca rosea* root extract on the growth and development of *Culex quinquefasciatus*

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ABSTRACT: Root extract of *Vinca rosea* caused prolongation of developmental period, larval and pupal mortality as well as various kinds of developmental abnormalities to *Culex quinquefasciatus*. 

KEYWORDS: *Culex quinquefasciatus*, *Vinca rosea*, mortality, developmental abnormalities

*Culex quinquefasciatus* (Diptera: Culicidae) is a vector of Bancroftian filariasis. In view of the widespread development of resistance to chemical insecticides by mosquitoes and the promising role of botanicals as pest control agents, the effect of root extract of *Vinca rosea* on the growth and development of *C. quinquifaciatus* was investigated.

Egg rafts of *C. quinquefasciatus* were collected from stagnant water bodies near the college campus, washed with tap water and allowed to hatch in laboratory conditions (28 ± 2 °C and 75 ± 5% RH). The larvae were reared in plastic containers with commercial fish meal as food. The adult mosquitoes were maintained in cages, 25 cm × 25 cm × 25 cm.

*Vinca rosea* plants were collected from different places in Coimbatore District. The root was washed with distilled water, shade dried and electrically grounded. The ground material was then stirred with acetone for 24 h and the suspension filtered. The residue obtained was washed with ether and further soaked in absolute methanol for 48 h to ensure complete extraction. The resulting extract was then evaporated to dryness and the residue was reconstituted with acetone to give the desired concentration and used for bioassay.

Twenty freshly laid eggs, newly emerged IV instar larvae and freshly moulted pupae of *C. quinquefasciatus* were exposed to different concentrations of root extract. Control was maintained with acetone. Mortality of the developmental stages was observed over a period of 24 h. Behavioral changes and abnormalities in development were also noted. $LC_{50}/24$ h value was determined following Finney (1971).

TABLE 1. Relative toxicity of *Vinca rosea* crude root extract on different life stages of *Culex quinquifaciatus*

| Life stage of the insect | Chi-square | Regression equation | $r$ | $p$ | $LC_{50}$ | Fiducial limits | Relative toxicity |
|---|---|---|---|---|---|---|---|
| Egg | 0.163 | $Y = 6.510655 + 24.826372X$ | −0.060849 | 0.040280 | 0.869 | 0.842–0.892 | 145 |
| Larva | 4.710 | $Y = 8.235250 + 1.451696X$ | −2.228601 | 0.688849 | 0.006 | 0.003–0.009 | 1 |
| Pupa | 1.969 | $Y = 9.043757 + 12.842858X$ | −0.314864 | 0.077864 | 0.484 | 0.459–0.519 | 80 |

Hatching of eggs and mortality of larvae and pupae were recorded at 24 h intervals. Dead larvae, pupae, partially emerged or deformed adults were regularly removed and counted. Live pupae were collected and observed till emergence. Morphogenetic abnormalities were studied on larvae, pupae and adults.

The following morphogenetic abnormalities were noted: enlarged pupae, partially exuviated adults with part of abdomen still in pupal case, attachment of legs to pupal case, deformities on the abdomen still in pupal case, and deformities of wings like twisting, unevenness, incomplete development and disorientation of fore and hind wings. Deformed adults failed to detach themselves from their pupal case.

Larvae exposed to different concentrations of root extract showed extension of developmental period and mortality. The surviving larvae often showed S or U shaped postures and stretching. Such U shaped postures and stretching have been described previously as characteristic of mosquito larvae reared in water treated with *Melia volkensii* fruit extract (Mwangi and Mukiama, 1988). In the present study the root extract showed different degree of toxicity to egg, IV instar larvae, and pupae. The $LC_{50}$ values for the egg, IV instar larvae and pupae were 0.869, 0.006, 0.484 mg/ml (Table 1). The extract required for 50% kill of egg and pupa were 145 and 80 times more than that for the larva.

Mortality of late IV instar larvae and adults of *Aedes aegypti* and *C. quinquefasciatus* treated with *Lantana camera* leaf extract was reported by Anyanwu and Uloko (1997). Similarly mosquito larvicidal effect of citrus lemon extract was reported by Anyanwu *et al.* (2001).

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# Influence of sugar concentration in the food source on the foraging behaviour of *Apis mellifera*

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ABSTRACT: The foraging behavior of *Apis mellifera* with reference to the sugar content of the food source was studied. The experiment showed that 40% and 50% sugar solutions did not show significant difference in the number of bees visiting the food source or in the quantity of food removed in two hours. In 60% sugar solution the visiting foragers were less and quantity of food removed by the bees was also less. Such preference may be occurring in selecting nectar source in nature also.


KEYWORDS: honey bee, sugar syrup, foraging behaviour

The foraging behavior of honey bees in collecting nectar will influence the health and build up of the colony and also honey yield from the colony. The amount of nectar the worker honey bee imbibes and retains in her stomach is influenced by the sugar concentration, the availability of nectar and the age and experience of bees. Singh *et al.* (1989) reported that among the Indian honey bees the liquid load carrying capacity is the highest in *Apis dorsata* while *A. florea* carried less quantity.

The aim of the present study was to assess the variations in food collection of *A. mellifera*, with reference to the sugar concentration in food source.

Influence of varying concentrations of sugar solution (40, 50 and 60%) provided in open petri dishes at a distance of 25 m from the hive, and the quantity of the food intake by the forager bees were assessed in an experiment. Forager bees of experimental colonies were trained on known concentrations of sugar syrup. After training of the bees 80 g of sugar solution was taken in open Petri-dishes and each dish was weighed. For each replication of a treatment two pairs of Petri-dishes were taken and one of them was kept as control to assess the loss of weight by evaporation and the same was

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TABLE 1. Food intake of foraging bees of *Apis mellifera* when presented with various concentrations of sugar solution

| Concentration of sugar solution (%) | Number of bees visiting | | Mean quantity of the sugar solution imbibed/bee (g) | | Body weight of bees (g) |
|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | |
| 40 | 160–240 | 207.5 | 0.300–0.331 | 0.273 | 0.12 |
| 50 | 180–236 | 213.1 | 0.230–0.272 | 0.255 | 0.10 |
| 60 | 172–212 | 190 | 0.191–0.274 | 0.241 | 0.12 |

kept away from the approach of the bees. Bees were allowed to feed on the sugar syrup kept in the other Petri-dish and the number of bees leaving the Petri-dish after taking the syrup was continuously observed and counted. More than 100 bees visited the Petri-dish in two hours and the quantity of the sugar syrup left in the Petri-dish was weighed to know the quantity of syrup carried by the bees. The loss of evaporation was determined from the corresponding control dish and the loss due to evaporation was subtracted to calculate the actual quantity of syrup carried by the bees. The actual quantity of syrup carried by the bees was divided by the total number of the bees to find the mean quantity carried by individual bee and the same was treated as the average nectar carrying capacity of the bee. Ten replications were maintained for each treatment.

Data presented in Table 1 show that the bees prefered sugar solutions of higher dilutions since more number of bees (mean 207.5 and 213.1) chose 40% and 50% solutions than 60% solution (190). The quantity of sugar solution 40% and 50% imbibed by the bees did not show wide variation (mean 0.273 g and 0.255 g) while in 60% the quantity was 0.241 g. Thus the results indicate that the foraging bees showed slight preference to food with lesser sugar content and the same may hold good in the selection of nectar in nature too.

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# Studies on syrphid species complex and their natural enemies in sugarcane ecosystem in northern Karnataka

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ABSTRACT: Syrphids are important predators of sugarcane woolly aphid. The syrphid species complex and their natural enemies in sugarcane ecosystem in Khanapur, Sankeswar and Dharwad taluks in Karnataka were studied. Two species, *Eupeodes confrater* and *Dideopsis aegrota* were recorded. *E. confrator* was the major species occurring in all the locations and the only species recorded in some locations. This species was attacked by a larval-pupal parasitoid, *Diplazon laetatorius* and three species of bacterial pathogens viz., *Citrobactor* sp., *Aeromonas* sp. and *Bacillus* sp. The parasitization ranged from 0 to 23.5 per cent with peak infestation in October. The incidence of bacterial infection ranged from 0 to 20 per cent, also with peak in October. 

KEYWORDS: syrphids, *Eupeodes confrater*, sugarcane woolly aphid

The sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner is a major pest of sugarcane (Patil *et al*., 2004). Losses to the tune of 26% in cane yield and 24% in sugar content have been reported (Shankar and Shitole, 2004). Although syrphids are important predators of *C. lanigera* not much attention has been paid to make detailed studies on them. This study was undertaken to know the species complex of syrphids and their natural enemies in sugarcane ecosystem in northern Karnataka.

The studies were made during 2005 at UAS, Dharwad. To identify the syrphid species present, fifty syrphid larvae were collected randomly from each woolly aphid infested field, once in a month from Khanapur and Sankeshwar and once in a week from Dharwad. The larvae were reared up to adult stage in separate labelled rearing cages by providing fresh woolly aphids every day. The emerging flies were grouped into different categories based on morphological features and counted. Samples from each category were identified with the help of Project Directorate of Biological Control (PDBC), Bangalore.

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TABLE 1. Occurrence of syrphid species in sugarcane ecosystem at different locations

| Location[1] | % Species composition | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | September | | October | | November | | December | |
| | *E. Confrater* | *D. aegrota* | *E. confrater* | *D. aegrota* | *E. confrater* | *D. aegrota* | *E. confrater* | *D. aegrota* |
| **Khanapur *** | | | | | | | | |
| Gandigawad | 62.58 | 37.42 | 65.96 | 34.04 | 68.24 | 31.76 | 69.12 | 30.88 |
| Ambolli | 63.63 | 36.36 | 69.23 | 30.77 | 69.69 | 30.30 | 68.88 | 31.12 |
| **Sankeshwar** | | | | | | | | |
| ARS, Sankeshwar | 100 | 0 | 100 | 0 | 95.83 | 04.16 | 97.26 | 02.74 |
| Sultanpur | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| **Dharwad** | | | | | | | | |
| Narendra | | | | | | | | |
| 1st week | 100 | 0 | 100 | 0 | 93.75 | 06.25 | 84.61 | 15.38 |
| 2nd week | 100 | 0 | 100 | 0 | 86.66 | 13.33 | 85.71 | 14.28 |
| 3rd week | 100 | 0 | 100 | 0 | 90.90 | 09.09 | 91.30 | 08.69 |
| 4th week | 100 | 0 | 100 | 0 | 100 | 0 | 90.70 | 09.30 |
| Saidapur | | | | | | | | |
| 1st week | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 2nd week | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 3rd week | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| 4th week | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |

[1]Places in bold letters are 'taluks'; others are villages. Percentages are based on 50 larvae collected from each village. *Places closer to forest area

TABLE 2. Occurrence of natural enemies on *E. confrater*

| Month | % Parasitisation by *D. laetatorius* | % Disease incidence* |
|---|---|---|
| September | 0 | 0 |
| October | 22.50 | 20.00 |
| November | 25.00 | 17.50 |
| December | 15.00 | 12.50 |

**Citrobactor* sp., *Aeromonas* sp. and *Bacillus* sp.

To identify the natural enemies, 20 eggs and larvae of the syrphids were collected from sugarcane field during different months and reared in the laboratory providing woolly aphids every day. Observations were made on parasitoid emergence and disease occurrence. The parasitoids and pathogens were identified with the help of PDBC.

The results are presented in Tables 1 and 2. Two syrphid predators of the sugarcane woolly aphid were recorded viz., *Eupeodes confrater* and *Dideopsis aegrota*. Among these, *E. confrater* was the dominant species in all the locations. In September and October, except in Gandigawad and Ambolli villages of Khanapur taluk, cent per cent of the syrphid population comprised this species (Table 1). The population of *D. aegrota* made up 2.74–37.42% of the total over the various months except in Saidapur village of Dharwad taluk and Sultanpur village of Sankeshwar taluk where it was never recorded. The latter species was more prevalent in places nearer to forest area.

Earlier records of syrphid predators of sugarcane woolly aphid include *E. confrater* from Nagaland (Tripathi, 1995), *E. confrater* and *D. aegrota* from Maharashtra (Patil, 2003) and *Metasyrphus confrater* and *D. aegrota* from Karnataka (Puttannavar, 2004)

Natural enemies of the syrphid, *E. confrater* recorded in this study include larval-pupal parasitoid, *Diplazon laetatorius* (Hymenoptera: Ichneumonidae) and the bacteria, *Citrobactor* sp., *Aeromonas* sp. and *Bacillus* sp. Parasitisation was nil September, high in October–November (22.5–25%) and low in December (15%). Disease incidence also showed a similar trend.

Bhatia and Shaffi (1933), Schneider (1969), Verma and Makhmoor (1989), Greco (1997) and Tineku *et al.* (1998) also had reported *D. laetatorius* as an important parasitoid of syrphids. According to Verma and Makhmoor (1989), *Bacillus* sp. caused maximum mortality of all the larval instars of syrphids. Schneider (1969) recorded 45.5% larval mortality due to *Bacillus* under field conditions and 31–32% and 21–22% mortality due to *Citrobacter* and *Aeromonas*, respectively, under laboratory conditions.

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# Host plant based biological variations in *Aphis gossypii* Glover populations (Hemiptera: Aphididae)

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ABSTRACT: *Aphis gossypii* populations from cotton, chilli, brinjal and arum host plants were tested for variations in biological attributes. Cotton and arum populations of *A. gossypii* showed distinguishable variations in adult weight, developmental time, generation time, reproductive duration, fecundity, intrinsic rate of increase and net reproductive rate. The results indicate that the phenotypes of *A. gossypii* inhabiting some host-plant species differ as a consequence of the contrasting feeding environments the host species provide, i.e., *A. gossypii* populations show host plant specialization. © 2009 Association for Advancement of Entomology

KEYWORDS: aphids, *Aphis gossypii*, host plant specialization

Asexual populations of the cotton aphid, *Aphis gossypii* Glover, a world wide pest in agriculture, horticulture and greenhouse crops (Agarwala and Ghosh, 1985; Blackman and Eastop, 1985) show clonal diversities in relation to host plants in several parts of the world (Inaizumi, 1981; Guldemond *et al.*, 1994). Guldemond *et al.* (1994) recorded significant differences in biological performance of *A. gossypii* from cucumber and chrysanthemum. He also found that *A. gossypii* population from cotton has lower reproduction on cucumber and okra. Available literature suggests that *A. gossypii* consist of various genotypes that are adapted to different host plants and might be considered as host races (Jaenike, 1981; Diehl and Bush, 1984; Agarwala and Das, 2007). In the present study, variations in biological performance of *A. gossypii* populations from cotton (*Gossypium hirsutum*), chilli (*Capsicum annum*), brinjal (*Solanum melongena*) and arum (*Colocasia esculenta*) in India were tested.

Laboratory clones of *A. gossypii* were developed on their respective host plants under greenhouse conditions following the method of Agarwala and Das (2007). These nymphs were placed individually on detached leaves of respective host plants in Petri dishes, one leaf with one aphid in each Petri dish, in a low temperature incubator at 22° ± 1°C to develop and reproduce. In each leaf, only one nymph of a reproducing

*Corresponding author

female in the first generation was retained and rest removed. All the nymphs born to individual adult apterous aphids in the second generation were counted. Ten replicates for each host plant species were used in the study. Leaves were changed every 24 h by fresh ones to maintain the vigour of experimental culture. Weights of aphids were taken in a 'Mettler' electronic balance sensitive to $0.2\mu$ g.

The following biological attributes were studied: birth weight (BW) of nymphs laid by apterous females within 12 h of laying; adult weight (AW) recorded within 12 h of final moult; developmental time (DT) in days from the birth of a nymph to its final moult; generation time (GT) in days from the birth of a nymph to the time of onset of reproduction by this nymph; reproductive duration (RT) in days from the first birth of nymph to the last birth by an apterous adult, and fecundity (F) as the number of nymphs born to a mother aphid. In addition, the following biological functions were also determined. Net reproductive rate ($R_0$), which is the multiplication rate of an organism per generation in terms of number of female offspring produced by a cohort of females was calculated by the formula: $R_0 = \sum x.lx.bx$, where $lx$ is the proportion of females surviving in a cohort, $bx$ is the number of female offspring produced per female during its reproductive time and $x$ is the age of the female adult. Intrinsic rate of increase (*Rmax*), which is a measure of rate of increase of population under controlled conditions, was calculated by the formula (Krebs, 1985): $R_{\max} = \sum \log_e (R_0)/G$, where $R_0$ is the net reproductive rate and $G$ is the mean length of generation, determined by the formula: $G = x.lx.bx/R_0$.

Differences in biological functions in different *A. gossypii* clones were analyzed with Tukey's multiple range test.

Results (Table 1) showed that AW, F and RT of aphids from the four host plant species were significantly different from each other. The F in aphids from cotton was twice that of aphids from arum plants. However, no such difference was noticed in respect of BW, DT and GT although aphids from cotton and arum plants showed significant differences in DT and GT.

Results further showed that the *Rmax* was the highest in aphids on arum leaves, and the lowest on brinjal leaves. Aphids from cotton and chilli plants showed nearly similar *Rmax* but these were significantly different from the *Rmax* recorded on arum and cotton plants. In contrast, $R_0$ was recorded to be the highest in aphids on cotton plants and the lowest on arum plants with a difference of about 95% between these values.

This study suggested that *A. gossypii* from different host plants showed biologically different forms. Earlier, Agarwala and Das (2007) showed distinguishable variations in morphology, ecological performance and esterase pattern of *A. gossypii* populations from these hosts. Therefore *A. gossypii* should be regarded as a heterogenous species infesting various host plants at different rates, that is, *A. gossypii* showed host plant specialization. This implies that no or little infestation of *A. gossypii* populations will occur from one plant species to another. This was shown in *A. gossypii* populations occurring on cucumber and chrysanthemum (Guldemond *et al.*, 1994). Recent studies on *A. gossypii* (Wool and Hales, 1996; Vanlerberghe-Masutti and Chavigny, 1998;

TABLE 1. Variations in biological functions of apterous adult morph of *A. gossypii* clones obtained from four plant species

| Biological attributes | Mean of measurements ($n$ = 10) | | | |
|---|---|---|---|---|
| | Cotton | Brinjal | Chilli | Arum |
| BW (mg) | 0.014[a] | 0.01[a] | 0.012[a] | 0.01[a] |
| AW (mg) | 0.124[a] | 0.92[b] | 0.101[c] | 0.085[d] |
| DT (days) | 6.80[a] | 6.60[b] | 6.10[ac] | 5.70[bc] |
| GT (days) | 7.70[a] | 7.60[ab] | 7.10[ac] | 6.80[bc] |
| RT (days) | 11.30[a] | 16.20[b] | 11.13[a] | 7.10[c] |
| F (no.) | 44.10[a] | 34.70[b] | 27.00[bc] | 21.70[c] |
| $R_{max}$ (aphid no./ mother/day) | 0.297[a] | 0.191[b] | 0.286[ac] | 0.342[c] |
| $R_0$ (aphid no./ female/ GT) | 43.65[a] | 33.58[b] | 31.87[b] | 25.21[c] |

Dissimilar letters with mean values in a row indicate significant differences by Tukey's multiple range test.
BW, birth weight; AW, adult weight; DT, developmental time; GT, generation time; RT, reproductive duration; F, fecundity; $R_{max}$, Instrinsic rate of increase; $R_0$, Net reproductive rate.

Fuller *et al.*, 1999) suggest that its evolutionary potential to adapt to newer host plants might be quite large and it holds the potential of becoming pest on an increasing number of crops.


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Book Review

# Research on Chrysomelidae, vol. 1

## Editors: Pierre Jolivet, Jorge Santiago-Blay and Michael Schmitt

## Brill Publishers, Leiden, The Netherlands, 2008, 430 pp.

This collective/edited book is the first volume in a proposed series to give a composite picture of progress in the study of a very large family of beetles, Chrysomelidae, with more than 40,000 recorded species, which number is steadily increasing. The contents are organized in eight Sections: Phylogeny and Molecular Biology, Morphology and Anatomy, Palaeontology, Relations to Plants, Biological and Ecological Studies, Taxonomy and Faunistics, Population Biology, and Parasitology.

In Section 1, Jesus Gomez-Zurita has discussed the process of speciation in the enigmatic genus *Timarcha*, on the basis of genetic and phylogenetic studies and has inferred that while most species of the genus have evolved in allopatry, sympatric speciation has also occurred due to chromosomal changes or host plant shifts or both. Host plant shift has also been discussed by Eben and Monteros in their contribution, "Specialization is not dead end: further evidence from Diabroticina beetles". They have worked out phylogenies of beetles of the Subtribe Diabroticina (Subfamily Galerucinae) on the basis of molecular data. From the phylogenies they have inferred that the ancestral stage for the subtribe was monophagous and specialized for feeding on plants of Fabaceae but specialization is not a dead end in evolutionary process, and further evolution may lead to oligophagy/polyphagy. In another chapter Eben *et al.* trace the evolutionary history of Diabroticina. Kergoat, Delobel, Ru and Silvain in their chapter have discussed the systematics of bruchids (bruchines for these authors) in the light of available molecular data for this group.

In Section 2, Scholler gives an account of comparative morphology of sclerites used by Camptosomatan leaf beetles for formation of extrachorion and hopes that "the pattern of sclerites (will) provide, most likely a valuable character set for phylogenetic studies on Camptosomata". Nesterova has described larval morphology and developmental history of two sibling species of *Galerucella nymphaeae* and *G. aquatica*. Mikhailov has made a meticulous study of body colour variation in *Oreina* and *Crosita*, and has inferred correlation between body colouration and altitude/season. Verma has discussed the taxonomic significance, variability, and evolution of male genitalia in insects, with particular reference to Chrysomelidae and has inferred that evolution of the genitalia has been guided by a mosaic of factors, including sperm competition, cryptic female choice, sexual conflict, coadaptation of male and female genitalia,

and in some cases even resistance to mite infection of the genitalic parts. Beenen and Jolivet have discussed the taxonomic position of the leaf beetles with shortened elytra (brachelytrous condition) and also their habitat, and show that such forms occur in alpine habitats, desert areas, and oceanic islands. They discuss the advantage of shortened elytra in such stressing conditions.

In Section 3, Elias and Kuzmina have reviewed "Response of Chrysomelidae to Quaternary environmental changes" and show that the chrysomelids dominating among the abundant insect fossils from the Quaternary period, particularly in Eurasia, "match modern species exactly".

In Section 4, Flinte, de Macedo, and Monteiro have documented the food plants for 35 out of 51 species under 21 genera of Cassidinae in the tropical rain forests of Brazil and describe the oviposition pattern and larval behaviour of some species. Medeiros and Moreira have concentrated on food plant choice of one cassidine species in Brazil, *Gratiana spadicea* which is regarded as monophagous on *Solanum sisymbriifolium*.

In the next section, Heron has given a detailed account of life-history of the cassidine *Aspidimorpha submutata*. Vencl and Nishida have described a new species of *Oulema* (Criocerinae), larva of which produces galls on various parts of the monocotyledonous *Commelina* plant, a rare habit among beetles. Bontems and Lee have recorded a new case of viviparity in *Agrosteomela chinensis* (Chrysomelinae).

In Section 6, Biondi and Alessandro have given a revision of the *Chaetocnema pulla* group of species along with description of a new species from Central Africa. LeSage has discussed the small taxonomic differences between *Altica knabii* and *A. pedipallida* (Alticinae). Jolivet and Verma have discussed the origin of the disharmonious and enigmatic chrysomelid fauna of New Caledonia which includes both vicariant forms representing lineages of the Gondwanan origin and forms which have reached the islands by dispersal from Indonesia and other neighbouring land masses in recent times.

In Section 7, Grenha, de Macedo, and Monteiro have discussed the population fluctuation in the cassidine *Mecistomela marginata* on the palm *Allagoptera arenaria*. Lam, Krell, Bradshaw, Rice, and Pedigo have discussed the development, verification and use of mathematical models in planning pest control strategy for the bean leaf beetle *Cerotoma trifurcata*.

Section 8 includes only one paper, by Cuignet, Windsor, Reardon and Hance on diversity and specificity of parasitoids attacking Neotropical Cassidinae. Of these parasitoids more than half the species belong to Eulophidae.

Those interested in the study of Chrysomelidae feel obliged to Prof. P. Jolivet of Paris, who, along with some of his equally zealous colleagues, has edited a series of books on biology of leaf beetles, providing a ready reference on current trends of research on these beetles. These include *Biology of Chrysomelidae* (1988) (Eds. P. Jolivet, E. Petitpierre & T. H. Hsiao), *Novel Aspects of the Biology of Chrysomelidae* (1994) (Eds. P. Jolivet, M. L. Cox & E. Petitpierre), *Chrysomelidae Biology*, 3 volumes (1996) (Eds. P. Jolivet & M. L. Cox), *New Developments in the Biology of Chrysomelidae* (2004) (Eds. P. Jolivet, J.A. Santiago-Blay & M. Schmitt), and now *Research on Chrysomelidae*, vol. 1 (2008) which is reviewed here. Vol. 2 of the last title is expected to be in print soon.

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Jalaja M., Muraleedharan D. and Prabhu V. K. K. (1973) Effect of extirpation of median neurosecretory cells on reproduction in the female red cotton bug, *Dysdercus cingulatus*. Journal of Insect Physiology, 19(1): 29–36.

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